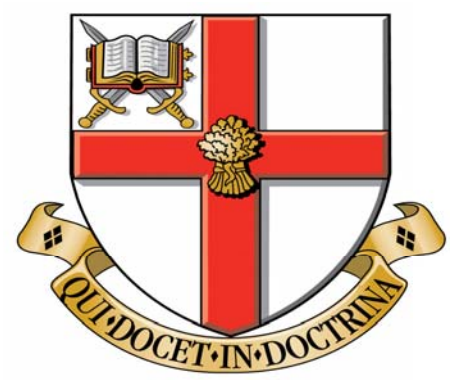


University of Chester

University of Chester

Department of Clinical Sciences

PhD Thesis

Title: Alternative methods of treating atelectasis in post-operative patients

Student Name: Fouad ALMutairi

Student Number: 0719092

ACKNOWLEDGEMENTS

First of all, I am thankful to God the most Merciful for giving me the patience, perseverance and courage to finish this work.

I hope to express my profound gratitude to my parents and my wife, for their prayers and all their sacrifices that they have made for me. Great thanks to my brother, my sisters and the rest of my family who pray for me. I offer them my heartfelt wishes.

I would like to express my special thanks and gratitude to my principal supervisor, Dr. Stephen Fallows. Without Dr. Fallows' invaluable advice, guidance, positive attitude and encouraging remarks, this PhD thesis could not have been completed. I also would like to express my special thanks and gratitude to my second supervisor Prof. Elizabeth Mason-Whitehead, and Dr. Mike Morris and other members in the Clinical Science department in University of Chester.

Finally, I would like to express my deepest gratitude and appreciation to my local medical advisers Dr. Wallid Abukhudair and Dr Bhrul Islam, and also Charissa V. Belleza, Maria Theresa Cerda, Josephine C. Malgapo, Maria Fe S. Quejadas, Marilou D. Gime, and Eleonor B. Paligutan in the Respiratory Therapy Department and Cardiac unit at King Fahd Armed Forces Hospital in Kingdom of Saudi Arabia. Indeed, they were very helpful, understanding and assisted greatly with the recruitment for this study.

RESEARCH ABSTRACT

Objective

Cardiac surgery incisional pain can decrease inspiratory effort, alter normal respiratory mechanics, and increase the potential for post-operative pulmonary complications. Post-surgical atelectasis is the most frequent complication after coronary artery bypass grafting (CABG), ranging from 54% to 92%. All types of therapy such as an incentive spirometry (IS), deep breathing exercises (DBE) or continuous positive airway pressure (CPAP) have a valuable role to play in the prevention or the treatment of post-surgical atelectasis. However, the type of therapy that should be used is not completely clear yet.

The present research aims to evaluate the benefit of early use of CPAP via mask therapy to treat or prevent post-surgical atelectasis after CABG, particularly in smokers and elderly patients, as compared to regular (IS) therapy. Also, it aims to evaluate the patients' and medical staff's experience about the use of the new method of CPAP via mask therapy.

Methods

The present research was conducted at King Fahd Armed Forces Hospital in Saudi Arabia between March 2010 and December 2011. It used a mixed methods approach. The first two studies were intervention quantitative studies, which investigated the benefit of CPAP via mask therapy. The others were qualitative studies that evaluated the experience of patients and medical staff regarding CPAP therapy use.

Results

A total of 180 patients (male and female) (36 in each group) participated in the two quantitative studies. Ninety two participants (male and female) participated in the qualitative studies. The first quantitative study results showed an improvement in CPAP via mask therapy for half hours every two hours group measurements as compared to IS therapy groups. IC was increased significantly in the "CPAP every two hours group" as compared to control group (IS) (baseline mean for IS group 1.34L and "CPAP every two hours group" 1.42L, post- therapy mean 1.59L and 1.88L respectively, p= 0.037). In addition, when chest physiotherapy was added to the two regimens, the improvement of CPAP therapy measurements became more than IS therapy. Moreover, the patient's acceptance rate for CPAP therapy every two hours was 93% and the medical staff acceptance rate was 86%.

Conclusion

CPAP via mask therapy for half hour every two hours had better outcomes in treating or preventing post-surgical atelectasis after CABG, particularly in smokers and elderly patients. Adding chest physiotherapy led to even better outcomes. The use of the new method of CPAP therapy had high acceptance rate by the participants and medical staff.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Airway Resistance……	Raw
American Association for Respiratory Care.....	AARC
Arterial Oxygen tension……..	PaO_2
Bi-level Positive Airway Pressure.....	BiPAP
Blood Pressure.....	BP
Cardiopulmonary bypass.....	CPB
ChestPhysiotherapy……..……	CPT
Chronic Obstructive Pulmonary Disease.....	COPD
Coronary Artery Bypass Grafting.....	CABG
Coronary Artery Disease.....	CAD
Coronary Cardiac Unit ……..	CCU
Continuous Positive Airway Pressure ……...	CPAP
Current Volume.....	CV
Deep Breathing Exercises.....	DBE
Expiratory Positive Airway Pressure.....	EPAP
Force Expiratory Volume in one second.....	FEV_1
Force Vital Capacity.....	FVC
Functional Residual Capacity.....	FRC
Heart Rate……...	HR
Incentive Spirometry …….	IS
Inspiratory Positive Airway Pressure.....	IPAP
Inspiratory Resistance-Positive Expiratory Pressure.....	IR-PEP
Inspiratory Capacity ……..	IC

Intermittent Positive Pressure Breathing.....	IPPB
Kingdom of Saudi Arabia……..	KSA
King Fahd Armed Forces Hospital.....……..	KFAFH
Left Anterior Descending.....	LAD
Minute Ventilation.....	MV
Nasal mask Continuous Positive Airway Pressure.....	nCPAP
Non-invasive ventilation.....	NIV
Non-invasive Pressure Support Ventilation.....	NIPSV
Non-invasive Positive Pressure Ventilation.....	NPPV
Obstructive Sleep Apnea ……...	OSA
Oxygen Saturation …….	SpO_2
Partial Pressure of Carbon dioxide in arterial blood.....	$PaCO_2$
Peak Expiratory Flow.....	PEF
Percutaneous Coronary Intervention.....	PCI
Percutaneous transluminal coronary artery angioplasty.....	PTCA
Positive Expiratory Pressure …….	PEP
Post-operative Pulmonary Complications.....	PPCs
Respiratory Rate ……	RR
Saturation level of Oxygen in arterial blood.....	SaO_2
Sputum Induction …….…….	SI
Tidal Volume.....	TV
Transcutaneous electrical diaphragmatic stimulation.....	TEDS
Ventilation/Perfusion.....	V/Q
Vital Capacity.....	VC

Chapter 1

Introduction

1.1. Coronary artery disease:

Coronary artery disease (CAD) is a consequence of build-up of plaque on the inside of the coronary arteries, the blood vessels that supply oxygen rich blood to the heart muscle. Plaque occurs due a build up of calcium , high cholesterol level in the blood, and other substances that float in the blood and, over time, build up on the inside walls of the coronary arteries and other arteries (Gottlieb & Sliver, 2001). CAD (or in other term coronary heart disease (CHD), actually CHD occurred as a result of CAD) is one of the most common causes of death all over the world and is reported to be the reason for 25% of all deaths worldwide in 1997. The major risk factors for CHD are high blood sugar, high blood pressure, high cholesterol, smoking and low level of physical activity. In Saudi, there is a strong relationship between the increase of CHD and changes to three main CHD risk factors the difference in life style of Saudi population (high calories intake and less physical activity), obesity and smoking (Hakim et al., 2003).

The high percentage of deaths relating to CHD expected to increase worldwide particularly in developing countries due to changes in life style and people's diet. By 2020 the leading cause of morbidity and mortality worldwide will be CHD and the most affected countries will be the currently developing countries. This alert from the World Health Organization encourages

governments to work hard to reduce the modifiable risk factors for CHD (AlHabib et al., 2009).

The first national survey conducted in Saudi evaluating the prevalence of CAD is a study done by AlNozha and colleagues in 2004. The study took place over five year period (1995-2000) and includes patients' aged from 30 to 70 years. The results showed 944 from 17232 participants had CAD (5.5%). The Saudi males had higher incidence of CAD than females (6.6% and 4.4% respectively). The major risk factors were age, high blood pressure, smoking and high blood cholesterol. In a recent study by AlHabib et al., 2009, which included eight Saudi hospitals to investigate the current management of acute coronary syndrome (ACS). The result showed 77% of the participants were male with mean age of 57 years old and 39% of all participants (435 patients) were smokers.

Another study (Almahmeed, *et al.*, 2012) presented data which evaluated CAD in Africa and the Middle East as compared to western countries (UK, USA and Germany). The results showed the main risk factors that increase the incidence of CAD are smoking, high blood pressure, diabetes, high blood cholesterol and inactive lifestyle. The mortality rate as a result of cardiovascular disease in predicted to increase by 171% in Middle East countries from 1990 to 2020. Almahmeed, *et al.*, 2012, also presented data which compared Middle East countries' mortality for CAD with a number of western countries (see figure1). That shows elevated rates in the Middle East including Saudi. In addition, the number of smokers increased over the last three decades in Middle East countries, while the incidence of tobacco consumption in America decreased over the same period of time (see figure 2). There is no clear data about current Saudi smokers. Often, due to cultural reasons, people do not like to

talk about their regular tobacco consumption. However, based on last year's statistical report about cardiac surgery from the hospital where the present study was conducted, 90% of the CABG patients were smokers.

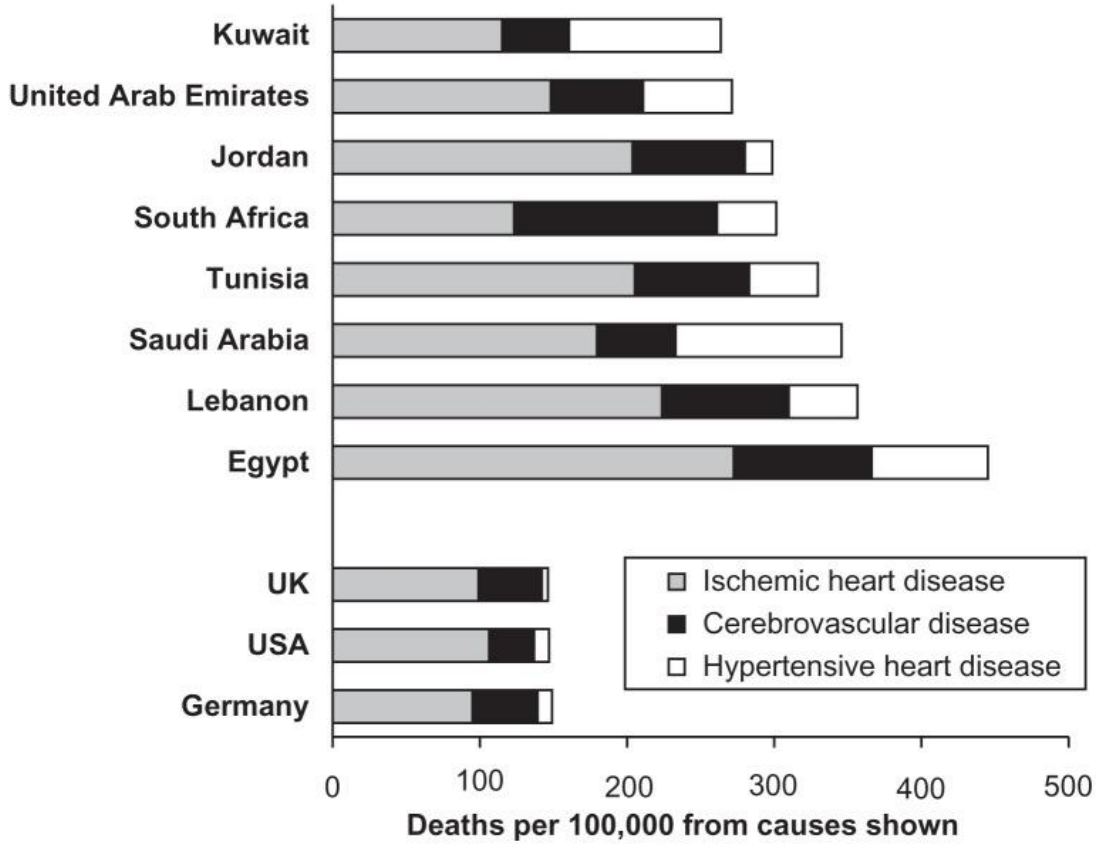


Figure 1: The mortality rate of cardiovascular disease (taken from Almahmeed, *et al.*, 2012).

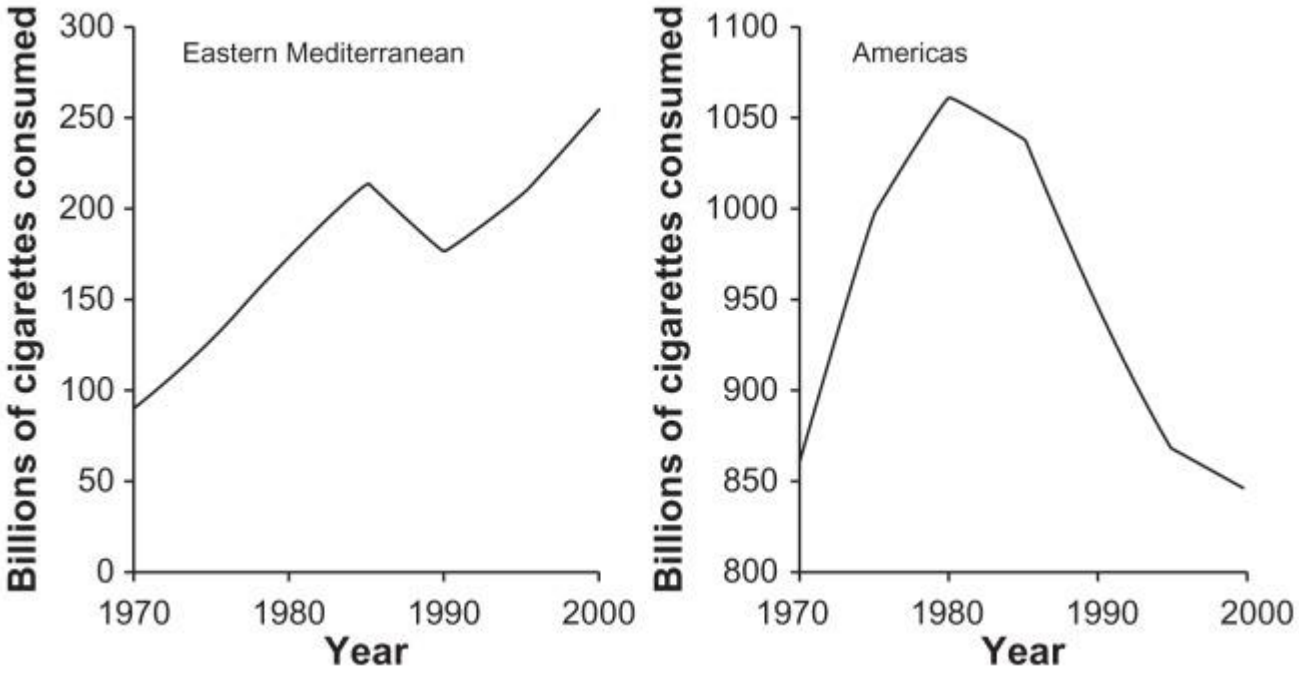


Figure 2: Trend in total cigarette consumption in Eastern Mediterranean and American regions (taken from Guindon, 2003).

The standard treatment for CAD is either via medication or via surgical procedures. The surgical treatment includes invasive (CABG) or non-invasive (PCI) options. Since the first coronary artery bypass grafting (CABG) procedure was introduced in 1967, trials of revascularization from the United States and Europe demonstrated improved survival with this technique in selected subgroups of high risk patients (for example, patients with left main coronary artery disease) (Varnauskas, 1988). The increase of the morbidity and mortality in CABG encouraged the development of percutaneous coronary intervention (PCI) or percutaneous transluminal coronary artery angioplasty (PTCA) in 1977 (Ford *et al*., 2007). Techniques of PCI have evolved more recently to include coronary artery stenting with bare-

metal stents and drug-eluting stents. Initially, the two revascularization techniques appeared complementary: the PCI technique for patients with limited lesions was less invasive, and the CABG technique for patients with diffuse disease, was more invasive (Hoffman et al., 2003).

The substantive study of the Duke University group recognized that PCI was better than CABG in patients with a single vessel disease, other than proximal left anterior descending (LAD) artery stenosis, and CABG was better than PCI in patients with multivessel disease, or proximal LAD artery stenosis. Patients with double vessel disease, or an isolated proximal LAD artery stenosis, had similar results with PCI and CABG. The final decision on the preferred technique of revascularization depends on clinical variables, for example, the characteristics of the stenosis, the patient's ventricular function, the age of the patient, and related co morbidities (Pretre & Turina, 2001).

There are 24 cardiac centers in Saudi that perform CABG procedure, but there is no specific data about the number of CABG surgery performed in Saudi. Saudi Ministry of Health reported in 2008, that the number of CABG procedure performed was approximately 14000, and this data was based on the statistical report about the CABG procedure in the Saudi Ministry of Health information system. However, not all the cardiac centers in Saudi were included in the Ministry of Health information system. The cardiac centers not included in the Ministry information system were a few, such as Military hospitals and National Guard hospitals. The health services in Saudi have worked hard in recent years to improve the diagnosis and treatment of CHD, and to reduce the modified risk factors such as smoking, diabetes and obesity (Saudi Ministry of Health, 2007).

There has been an improvement in non-invasive cardiac revascularization procedures, such as stents and balloon angioplasty over the last two decades. This has led to a reduction in invasive cardiac procedures. As a consequence, most of the CABG procedures are now adays performed on elderly patients, with medical co-morbidities. Moreover, the techniques of the invasive cardiac procedures have improved lately by using off pump, minimally invasive procedures (Mack et al., 2004; Northrup et al., 2004).

Despite these improvements in CABG procedures, post-operative pulmonary complications (PPCs) are still the major concern of the cardiac surgeons and medical staff involved in post-operative care. This is because PPCs usually result in increased morbidity and mortality, and also increased hospital stay. (Wynne & Botti, 2004). PPCs include hypoxemia, pneumonia and post-surgical atelectasis. Post-surgical atelectasis is the most frequent complication after CABG (Pasquina et al., 2004).

1.2. Atelectasis:

Atelectasis is a medical complication that may affect part of one lung or both lungs as a result of the lungs not inflating fully. It occurs when the alveoli are deflated as a result of pulmonary consolidation. It is a very common finding in chest x-rays and may be caused by strong exhalation or by several medical conditions. In addition, atelectasis is regularly described as a collapse of the lung tissue, but it is not identical with a collapsed lung, which is a more specific condition that features atelectasis (White, 2012).

Atelectasis may be either an acute or chronic condition. In adult patients, acute atelectasis may occur as a result of a post-operative complication. However, in chronic atelectasis, the

affected area is often characterized by a complex mixture of airlessness, infection, widening of the bronchi, destruction, and scarring (fibrosis) (Freitas, Soares, Cardoso & Atallah, 2007).

This research concentrates on acute atelectasis. The most common cause of acute atelectasis is post-surgical atelectasis, characterized by restricted breathing after abdominal or thoracic surgery. Smokers and elderly people are at an increased risk of atelectasis (Moritz, et al., 2007) and it is these groups of patients who were the target group in this research. The risk of acute atelectasis following surgery is increased by chest or abdominal pain, tight bandages, immobility of the body, abdominal swelling and sedatives (Fabienne et al., 2007).

The usual symptoms of atelectasis are coughing, chest pain, difficulty in breathing, low oxygen saturation and increased heart rate. Atelectasis is usually diagnosed by chest x-ray, and post-surgical atelectasis is bibasal in pattern. The factors that increase the risk of atelectasis include anaesthesia, prolonged bed rest with few changes in position, shallow breathing, and underlying lung diseases. In addition, in an adult, small regions of atelectasis are usually not life-threatening, since unaffected parts of the lung can compensate for the loss of function in the affected area. However, large-scale atelectasis may be life-threatening, especially in someone who has another lung disease or illness (Kanat, Golcuk, Teke & Golcuk, 2007).

Mucus that plugs the airway may lead to atelectasis. The goal of atelectasis treatment is to remove lung secretions and re-expand the affected lung tissue. Post-surgical atelectasis is usually treated by chest physiotherapy, focusing on deep breathing and encouraging coughing (Placidi et al., 2006).

1.3. Incentive Spirometry (IS):

1.2.1. Definition and History:

There is a high occurrence of post-operative pulmonary complications in cardiac surgery (range 20% to 95%). There are a large number of coronary artery bypass graft (CABG) operations performed in the world (Brooks, et al., 2001). As there is a high incidence of post CABG pulmonary complications, it can result in high mortality and increased hospital stay which can lead to increase in the cost of the surgery. Several studies such as (Lawrence et al., 1995; Ferguson 1999; Canet & Mazo, 2010) have been conducted in the last decade to recognize the patients at high risk of post cardiac surgery pulmonary complication and the best methods to treat or prevent these complications.

Incentive spirometry (the regular method to treat atelectasis) is often used as part of breathing exercise and is also used to prevent atelectasis after surgery (Agostini & Singh, 2009). According to Scuderi and Olsen (1989) the objectives of IS method of therapy are to improve the performance of inspiratory muscle, increase the inspiratory volumes and transpulmonary pressure, and create or restore the normal pattern of lung expansion. Also, once the IS therapy is used frequently on a regular basis airway patency might be maintained and alveoli atelectasis prevented or reversed.

Chuter, Weissman, Mathews and Starker, (1990) defined IS as an intervention therapy for post-operative patients to reduce the pulmonary complications and the therapy utilizes an incentive spirometer (shown in figure1) which describes a mechanical device used during the post-operative period to decrease pulmonary complications. It was common to reproduce a normal sighing and deep breathing, and using slow inspiration and deep breaths to keep

inspiration for prolonged periods by encouraging the patients through visual and/or audio feed back (American Association for Respiratory Care (AARC): Clinical Practice guidelines for incentive spirometry, 2011).

In addition, according to Overend et al., (2001) IS is a commonly used method of therapy for post-operative patients. However, the effectiveness of IS therapy has been questioned by several publications such as (Matte, Jacquet, Van Dyck & Goenen, 2000; Stiller et al., 1994; Jenkins, Soutar, Loukota, Johnson & Moxham, 1989). Other publications debate the role of IS therapy used for major post-operative patients (such as Pasquina, Tramers & Walder, 2003; Brooks et al., 2001; Overend et al., 2001).

All methods of therapy such as IS, coughing and breathing exercises or continuous positive airway pressure (CPAP) have a valuable role to play in the prevention, or the treatment of post-operative pulmonary complications. However, the type of therapy which should be used is not completely clear yet. For these reasons a different modality or an alternative method of therapy should be investigated through a prospective trial to clarify the difference in effectiveness between IS therapy and other therapy such as CPAP therapy to treat post-operative pulmonary complication in CABG patients.

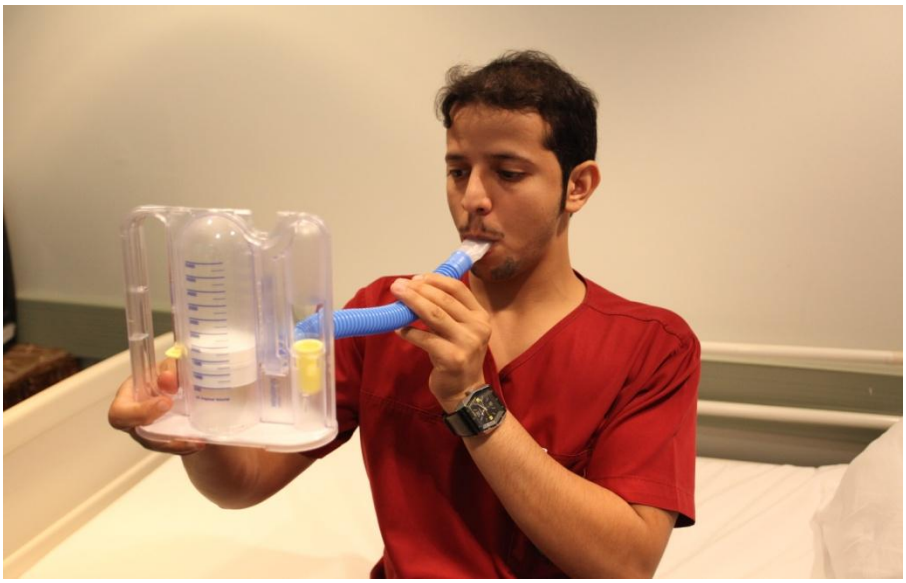


Figure 3. Shows IS Therapy Equipment

1.2.2. Indication and Contraindication of IS Use:

The major indications for IS use are post-operative upper abdominal or thorax surgery, condition predisposing to increased alveoli collapse such as abdominal binders, deprived pain, and immobility. Also, the presence of respiratory musculature deficiency relating to neuromuscular disease is an indication for IS use (Petz, 1979 and Overend et al., 2001).

- **Indications:**

According to American Association for Respiratory Care (AARC): Clinical Practice Guidelines for incentive spirometry, (2011).

- Presence of conditions leading to the development of pulmonary atelectasis.
- Upper-abdominal surgery.
- Cardiac and thoracic surgery.

- Post-operative patients with chronic obstructive pulmonary disease (COPD).
- Presence of acute atelectasis relating to pulmonary conditions.
- When the patient has quadraplegia and/or dysfunctional diaphragm associated with restrictive lung deficiency.

❖ **Contraindications:**

- Very difficult patient who cannot be supervised to assure proper use of IS device.
- Patient cooperation is absent or patient is unable to understand or demonstrate proper use of the device.
- When the patient is unable to do effective deep breathing (eg, with vital capacity less than about 10 mL/kg or inspiratory capacity (IC) less than about one third of predicted).
- The open tracheal stoma is a contraindication when the required version of IS device not available.

❖ **IS hazards and complications:**

- Uncooperative patient with IS device, unless closely supervised.
- Unsuitable as sole therapy for major lung collapse or consolidation.
- Hyperventilation.
- Barotrauma (emphysematous lungs).
-Discomfort secondary to inadequate pain control.
- The requirement of oxygen therapy if face mask or shield is being used and patient cannot tolerate discontinuation for short periods or oxygen via nasal cannula.
- Exacerbation of bronchospasm.
- Fatigue.

1.2.3. The Accepted Outcomes of IS Therapy:

According to Mang and Obermayer, (1989); Jenkins, et al., (1989); Scuderi and Olsen, (1989) and AARC Clinical Practice Guidelines for incentive spirometry, (2011). The accepted outcomes of IS therapy are:

- Absence or improvement in signs of atelectasis.
- Decreased respiratory rate.
- Resolution of fever.
- Normal pulse rate.
- Absent crackles (rales) or presence of or improvement in previously absent or diminished breath sounds.
- Normal chest x-ray.
- Decreased alveolar-arterial oxygen tension gradient and improved arterial oxygen tension (PaO_2).
- Increased VC and peak expiratory flows.
- Improvement of post-operative functional residual capacity (FRC) or VC values which return close to preoperative values in absence of lung resection.
- Improved inspiratory muscle performance.
- Attainment of preoperative flow and volume levels.
- Increased forced vital capacity (FVC).

1.4. Chest physiotherapy technique:

Chest physiotherapy (CPT) is a set of treatments aimed to improve respiratory efficiency, strengthen respiratory muscle, encourage lung expansion, and remove secretions from pulmonary system. It is another part of bronchial hygiene which refers to different techniques used to prevent the build-up of secretions, and mobilization of secretions once present. This may include turning, chest postural drainage, chest percussion and vibration, coughing and related expulsion techniques (Pryor et al., 2008).

The objectives of CPT are to aid in bronchial hygiene which means allowing the bronchial secretions to move to the central airways by means of gravity and external manipulation of the chest. It helps to remove secretions by effective cough or aspiration with the use of suction catheter. CPT is used in combination with other type of treatments such as inhaled bronchodilators and mucolytics. Improved mobilization of bronchial secretions contributes to improved ventilation efficiency and distribution, and improved cardiopulmonary reserve through physical training (Tang, Taylor & Blackstock, 2010).

1.4.1 Turning technique:

Turning is the turning round of the body in the region of the longitudinal axis and also called kinetic therapy or continuous lateral rotational therapy. It helps to encourage lung expansion and prevent retention of lung secretions. It improves arterial oxygenation, aids to mobilize airway secretions, and relieve dyspnea (Raoof et al., 1999). Normal turning can be to either side of the body or the prone position at any effective degree of the bed as indicated and tolerated. This is commonly done in combination with procedures intended to aid patient comfort and skin care. Consideration to chest position and or specific lung region or

segments is usually needed to ensure effective mobilization of the secretion. Patients may turn themselves or be assisted by a caregiver, or by a special bed or device (Ahrens, Kollef, Stewart & Shannon, 2004).

- **Indications:**

The main purpose of turning is to promote lung expansion, improve oxygenation, and prevent retention of secretions. It also helps to prevent skin ulcers and reduce venostasis. Specific indications for turning of patients with respiratory disorders are inability of patient to change body position such as patients receiving mechanical ventilation, patients with neuromuscular disease and drug- induced paralysis, immobility due to spinal injury, stroke, comatose and morbid obesity, insufficient oxygenation related with position; the presence or possible atelectasis; and the presence of artificial airways.

- **Contraindications:**

Unstable head or spinal cord injuries and traction of arm abductors are the two absolute contraindications for turning of patients. Relative contraindications were consist of diarrhea, marked agitation, increased intracranial pressure, hypotension by 10% drop in the blood pressure, worsening dyspnea or increased work of breathing, hypoxia or inadequacy of oxygen supply to the body tissue, and cardiac arrhythmias or irregularities of the heart rhythm. General hazards correlated with turning include accidental extubation from ventilator, accidental aspiration and disconnection of vascular lines catheters (AARC: Clinical Practice Guideline: Postural Drainage Therapy, 1991).

1.4.2 Postural drainage technique:

Postural drainage is a method of mobilizing and removing secretions by positioning the patient by the use of gravity to help drain the secretions. The goal is to move secretions from peripheral to more central airways for removal, prevention of the accumulation of lung secretions in patients having undergone abdominal or thoracic surgery. It encourages mobilization of the retained secretions in patients who have large amount of secretions (Fink, 2002). Postural drainage is effective in combination with aerosol therapy and other modes of CPT. The duration is usually 3 to 15 minutes per segment depending on the type of the secretion. Standard positions for postural drainage are adapted as the patient's conditions and tolerance warrant (Mcllwaine, 2007).

- **Indications:**

specific indications are includes difficulty in clearing the secretions, adults having difficulties expectorating sputum production greater than 25 – 30 mL/day, retained secretions in patients with artificial airways or presence of atelectasis with suspected mucus plugging. Other disorders related to impaired respiratory tract clearance such as cystic fibrosis, bronchiectasis, or presence of foreign body in airways.

- **Contraindication:**

An absolute condition includes head and neck injury, possible occurrence of active hemorrhage with hemodynamic instability or unstable function of the blood mechanics. Relative contraindications as the following: Intracranial pressure greater than 20 mm Hg, patients with increased intracranial pressure should avoid postural drainage method (example: neurosurgery, aneurysms, eye surgery); recent spinal surgery; active hemoptysis or

expectoration of blood from some part of the respiratory tract; empyema or presence of pus in a lung. Also, it includes cardiogenic pulmonary edema, large pleural effusion and pulmonary embolism, chest injury and rib fracture. Treatment schedule should be done either before or at least one to half hour after meals or tube feedings. In performing reverse trendelenberg position, potential risk of possible hypotension should be kept in mind (AARC: Clinical Practice Guideline: Postural Drainage Therapy, 1991).

1.4.3 Chest Percussion and Vibrations techniques

Percussion and vibrations both involves application of mechanical energy to the chest wall using either the hands or electrical or pneumatic devices. These deliberate methods are designed to breakdown the mucus from the chest wall and encourage airway clearance. Percussion method helps to loosen the retained secretion in the tracheobronchial tree making them easier to be coughed out. While, vibrations is designed to assist movement of secretions toward the central airways during exhalation phase of respiratory cycle (Hill, Patman & Brooks, 2010).

Chest percussion may also called cupping or clapping, due to it involves a manual rhythmic striking of the chest wall over a lung segment which is being drained with cupped hands in a systematic manner. The energy that it creates is transmitted through the chest wall to the lung and is able to dislodge secretions adhering to lung tissue in the bronchial walls. Percussion is performed during inspiration and expiration and used routinely with postural drainage. There are also devices that mechanically and pneumatically mimic the action of a manual percussion. Chest percussion is performed using a cupped hand and alternately clapping with both hands on the patient's chest wall. This should be applied over the lung

segment that needs to be drained and ideally. The procedure should be done back and forth in a rhythmic circular pattern over the affected area on the chest wall for duration of 3 to 5 minutes (Clinkscale, Spihlman, Watts, Rosenbluth & Kollef, 2012).

Chest vibration is another technique designed to breakdown and mobilizes secretions from the bronchial walls. It can be done either manually or mechanically. When done manually, it is performed by placing one hand on top of the other hand, over the affected region in the chest wall to be drained (Berney & Denehy, 2002). A rapid vibrating action (tremor) and slight pressure is applied through the arms and hands during exhalation to aid in mobilization of secretion. There are also mechanical devices used to perform vibration. However the difference between the manual method and mechanical devices is that the mechanical device can be applied continuously during both inspiration and exhalation (Chen et al., 2009).

- **Indications**

For chest percussion and vibration: Patients who are unable to expectorate sputum effectively despite receiving postural drainage therapy require additional management to facilitate movement of sputum towards the center of the airways. Particularly, chest percussion and vibration should be considered as an adjunct to postural drainage and coughing only when these methods alone fail to mobilize secretions from bronchial airways (AARC: Clinical Practice Guideline: Postural Drainage Therapy, 1991).

- **Contraindications:**

The absolute contraindication for chest percussion and vibration method is osteogenesis imperfecta or a group of genetic diseases of collagen in which the bones are formed

improperly, making them fragile and prone to breaking. Potential risks associated with percussion and vibration are subcutaneous emphysema or a presence of air in the tissue just under the skin , recent epidural spinal infusion or spinal anesthesia, recently placed transvenous or subcutaneous pacemaker, suspected pulmonary tuberculosis, lung contusion or worsening bronchospasm. Also, Osteomyelitis (refers to a bone infection) of the chest , thrombocytopenia (a condition that refers to an abnormal drop in the number of blood cells involved in forming blood clot) or chest-wall pain (AARC: Clinical Practice Guideline: Postural Drainage Therapy, 1991).

Coughing technique

Coughing is one of the most vital lung defence mechanisms and the most essential airway clearance technique; it is significantly impaired in patients with underlying infirmity, such as COPD, neuromuscular diseases etc. When the spontaneous cough is unsatisfactory to mobilize secretions, directed cough techniques are performed.

Directed cough technique is deliberate manoeuvres that are taught, supervised, and monitored. Cough efficiency is related to the volume of inspired air and the velocity of airflow during exhalation. Also, directed cough technique intends to reproduce the feature of an effective spontaneous cough, to help to provide voluntary control over reflex, and to compensate for physical limitations that can impair this reflex. Examples of this technique are huff coughing technique, force expiratory technique, and manually assisted cough technique. Directed cough may also be used to help obtain the sputum specimen for diagnostic analysis (Dias et al., 2011).

Cough instructions should be provided to patients who cannot generate an effective cough. First, patient should be properly positioned sitting up straight or leaning forward. Second, patients with an incision should be instructed on splinting the area with a pillow or any devices for support and held firmly over the area (Lingenderfer, 1998).

- **Indications:**

Directed cough may be used alone or in conjunction with other method of bronchial hygiene therapy. Indications for this technique are as follows: the need for clearing the retained secretions from the central airways; the presence of atelectasis or to prevent postoperative pulmonary complications. It can be used as a part of bronchial hygiene therapy in patients with cystic fibrosis, bronchiectasis, chronic bronchitis, necrotizing pulmonary infection, or to obtain sputum specimens for diagnostic analysis (AARC: Clincal Practice Guidelines: Direct Cough, 1993).

- **Contraindications:**

There are only few clinical situations that directed cough is contraindicated. However, contraindications must always be considered against the possible benefits of directed cough for each patient. The contraindications are unable to manage infection that spread by droplet nuclei (examples are mycobacterium and tuberculosis), known intracranial aneurysms or elevated incranial pressure, reduced coronary artery perfusion (example is acute myocardial infarction) and acute unstable head, neck or spine injury (AARC: Clincal Practice Guidelines: Direct Cough, 1993).

1.4.4 Complications and adverse effects of CPT:

Application of the various techniques of CPT may create risks to some patients. Among major complications of CPT are pulmonary hemorrhage, rib fractures, and cardiac arrhythmias. Lesser adverse effects include elevated intracranial pressure, increased airway resistance, decreased cardiac output, and hypoxemia. Proper precautions include the immediate availability of emergency airway devices, suction equipment, and oxygen therapy equipment must be considered first, prior to performing CPT techniques. Patients should also be observed throughout therapy for changes in the breathing pattern, pulse, and skin colour. In case of significant bronchospasm during procedure, bronchodilators and metered dose inhalers should be readily available (Varekojis et al., 2003).

Chest physiotherapy can be a valuable ingredient of comprehensive respiratory care, but only if used when indicated. Successful outcomes require careful patient assessment and selection, an apparent definition of therapeutic goals, systematic application of the appropriate technique, and ongoing assessment and follow up.

1.5. Continuous positive airway pressure (CPAP):

1.5.1 Definition and History:

The CPAP therapy is part of the main group of therapy called Non-invasive ventilation (NIV) or as alternative term is called non-invasive positive pressure ventilation (NPPV). NIV is defined as "the application of positive pressure via the upper respiratory tract for the purpose of augmenting alveolar ventilation" (Kramer, Meyer, Meharg, Cece & Hill, 1995). When NIV is applied in a proper way, respiratory distress improves faster, the requirement of endotracheal intubation may reduce, which leads to reduction in co-morbidity, mortality rate,

and length of hospital stay (Brochard et al., 1995; Thys, Roeseler, Reynaert, Liistro & Rodenstein, 2002).

According to Pierson (1997), the first device to provide NIV was bag mask equipment, used as alternative to mouth-to-mouth ventilation during resuscitation in 1780. However, the clinical use of NIV started with the introduction of intermittent positive pressure breathing (IPPB) in 1947 which was widely used to deliver medications via aerosol therapy for short periods of time, usually 10 to 15 minutes (Mehta & Hill, 2001). It was used successfully with acute respiratory failure in 1989, and since that time, NIV technique has significantly developed in NIV technology and patient interfaces (Freitas, et al., 2007).

NIV is a recognised therapy to treat acute respiratory failure particularly with COPD and neuromuscular diseases patients (British Thoracic Society Standards of Care Committee, 2002). According to Turner, Wright, Mendella, and Anthonisen (1995), the clinical evidence in the last two decades started to show that the benefits of intermittent positive pressure ventilation (IPPV) was often exaggerated and could be replaced with other simpler and cost-effective therapies. Since the introduction of nasal CPAP therapy in 1981 by Sullivan, Issa, Berthon-Jones and Eves, IPPV therapy lost favour in clinical practice and nasal mask continuous positive airway pressure (nCPAP) began to emerge as a highly effective therapy to treat OSA patients. CPAP therapy is a distending mechanical support pressure applied at a continuous level during the pulmonary cycle in order to sustain an open airway throughout sleep which obviates the effects of upper or lower airway collapsibility (Almendros, et al., 2008).

There are two types of CPAP therapy and both of them have their own applications and indications in the clinical setting. The first type is a CPAP generated by a flow generator and this type is used to provide respiratory support to treat type I respiratory failure. The second type is generated by a small, portable electrically powered compressor, and is usually used to treat OSA patients (Wang, et al., 1996).

1.5.2 Indications and Contraindications of CPAP Use:

The main indication for CPAP therapy is to treat hypoxemia in patients who have type I respiratory failure. Several clinical conditions can be a result of hypoxemia. Table 1 summarises the clinical indications and contraindications for the use of CPAP therapy according to American Association for Respiratory Care clinical practice guideline for CPAP use (1993).

Table 1. Summary of the clinical indications and contraindications for the use of CPAP

Clinical Indications for CPAP	Type I Respiratory Failure
	Acute cardiogenic pulmonary oedema
	Pneumonia
	Post-operative atelectasis
	Sputum retention
	Chest wall trauma
Clinical Contraindications for CPAP	Epistaxis
	Haemodynamic instability
	Facial trauma
	Type II respiratory failure (COPD)
	Severe haemoptysis
	Undrained pneumothorax
	Basal skull fracture
	Uncontrolled emesis
	Unconscious, with inability to protect airway
	Patient intolerance
	Asthma
	Poor patient-mask interface with large leak
	Hypotension
	Lung abscess
	Bullae
	Bronchial tumour in proximal airway
	Post-operative air leak

1.5.3. Principle of operation for CPAP:

The first type of CPAP therapy is created by a flow generator which is attached to oxygen blinder supply oxygen via high levels of pressure. The oxygen level is delivered via different types of mask (face or nasal mask) to the patients.

The patient breathes from a pressurised circuit during CPAP therapy against a threshold resistor (water-column, weighted, or spring loaded) that maintains consistent preset airway pressures from 5 to 20 cm H2O during both inhalation and exhalation. The exhalation pressures are set higher than atmospheric pressure and for that reason both inspiratory and expiratory pressures are increased (figure 4) (AARC, 1993).

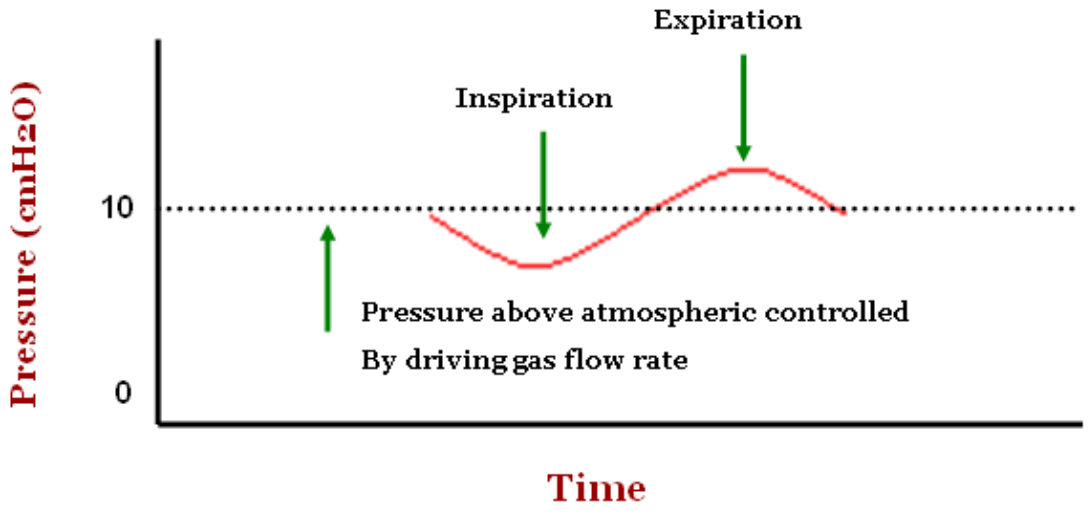


Figure 4. Continuous positive airway pressure

The second type of CPAP therapy is used in the treatment of OSA. This type of CPAP therapy is created by a small, portable electrical compressor and provides pressure at a continuous level throughout the breathing cycle. CPAP therapy provides a continuous pressure in order to sustain a patent airway for OSA patients during sleep which prevents the airway from collapse.

There are several modes of NIV delivery systems, that usually includes CPAP, inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP) mode. CPAP therapy mode is a baseline pressure that is set higher than atmospheric pressure when the patient breathes spontaneously. EPAP mode is a baseline pressure at end of expiration, while IPAP mode is the increase in airway pressure that occurs during inspiration (Figure 5) (Kallet & Diaz, 2009).

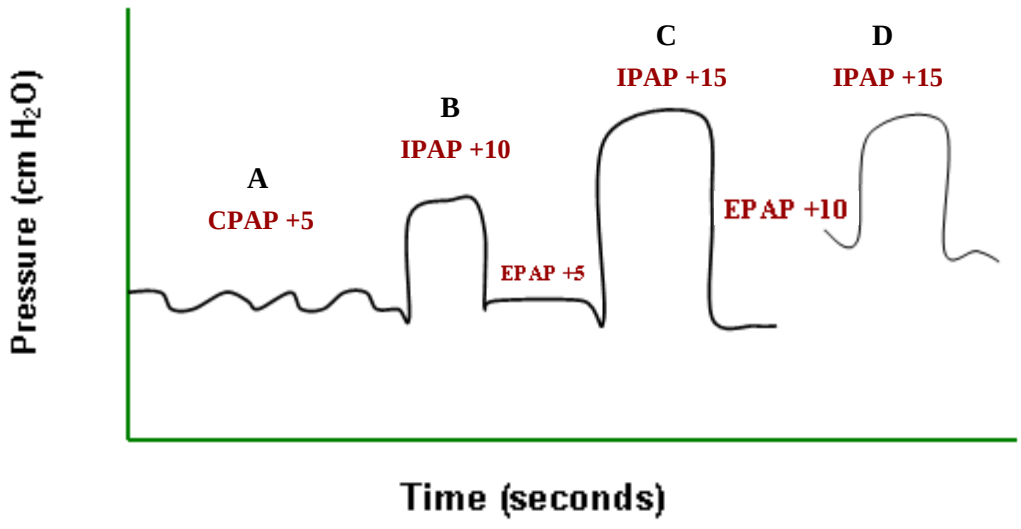


Figure 5. A, continuous positive airway pressure of 5 cm H2O with a patient breathing spontaneously. B, patient-triggered breath during NIV with an IPAP of 10 cm H2O and EPAP of 5 cm H2O. C, inspiratory positive airway

pressure has been increased to 15 cm H_2O. D, inspiratory positive airway pressure remains 15 cm H_2O, but EPAP has been increased to 10 cm H_2O.

1.5.4. Patient Interfaces:

Positive pressure ventilation is greatly influenced by the chosen interface to deliver the positive ventilation to patients. A variety of interfaces are available, including face masks, and nasal masks. Among all these interfaces, nasal masks are the most widely used for both NIV and CPAP. Nasal masks are preferable for long term ventilation but have also been used for acute hypercapnic and hypoxemic respiratory failure (Bardi, et al., 2000). The type of CPAP machine and the type of mask used for both intervention studies is shown in figure 6 below.

Figure 6. Shows CPAP Therapy

Chapter 2

Main literature review

2.1 Main literature review:

The main literature review contains three parts. The first part is a review of the previou studies relating to the field of this research. The second part is an overview of the functional anatomy and physiology of the pulmonary sysetm. The last part relates to the pulmonary function test variables and respiratory techniques used in this research.

Post-operative pulmonary complications (PPCs) are common after cardiac surgery. Since the start of cardiac surgery in 1953 several ways of therapy have been used to treat or prevent PPCs, particularly post-surgical atelectasis, due to its frequent occurrence after cardiac surgery. The present literature review includes all the available studies, trials or systemic reviews using one or more of respiratory physiotherapy methods or therapies to treat or prevent PPCs after major surgery, since cardiac surgery started, up to date. To identify the purpose of these studies, the previous studies were divided into four sections based on their aims and goals; the use of respiratory physiotherapy as single therapy, combined therapy, to prevent post-operative complications or as pre-operative management to prevent post-operative respiratory complications: each of these are discussed in date order.

2.1.1 Single respiratory physiotherapy:

Single respiratory physiotherapy is the use of any lung expansion method or therapy alone (such as deep breathing exercises (DBE), IS, CPAP and IPPB) to treat PPCs. Pefenniinger and Roth (1977), compared IPPB therapy and IS therapy in 20 post-operative patients, found significant difference in expanding lung volume created by IPPB therapy (IPPB value 2240 +/- 630 cc (mean+/-1SD and IS value 1960 +/- 650 cc, p value less than .005 by Wilicoxon test) which leads to decreased PPCs especially post-operative atelectasis. However, Iverson, Ecker, Fox and May (1978) study, compared IPPB, IS and blow bottles therapies to prevent atelectasis after cardiac surgery in 145 patients participating in the study using one of the three therapies. The result showed that PPCs increased in IPPB group by 30% compared to 15% in IS group and blow bottles group had only 8%. Also, 20 % of participants who used IPPB therapy developed gastrointestinal side effects, while the other group seldom developed it. The gastrointestinal side effect or extra air in the stomach is caused by most of the positive pressure applied system via mask (such as IPPB, CPAP and PEP therapies) and seems to be one of the most important reasons for failure of the therapy.

Gale and Sanders (1980) compared IPPB therapy with IS therapy after cardiac surgery in 109 patients who participated in the study. Vital Capacity (VC), arterial oxygen tension (PaO_2) and chest X-ray was used to compare the improvement in post-operative atelectasis in both groups. The results showed no significant difference between the two groups except that PaO_2 decreased after ten minutes in the IPPB group. However, IS therapy was used four times daily only in the study. Paul and Down (1981) evaluated the treatment of post-surgical atelecasis in post cardiac surgery patients. The results suggested that the use of CPAP via

mask therapy increases the lung volume which leads to improvement in post-surgical atelectasis. IS therapy had less effectiveness in terms of post-surgical atelectasis. However, the possibility of lung volume reduction after IPPB therapy was slightly higher as compared to other groups.

The efficacy of higher CPAP (more than 10 cmH_2O) via mask therapy has been evaluated to improve hypoxemia in 40 patients by Covelli, Weled and Beekman (1982). The result showed CPAP via mask therapy is a safe and effective treatment for hypoxemia associated with the early phase of respiratory distress. Stock et al. (1984) found out that most of post cardiac surgery patients developed a reduction in pulmonary function in first three post-operative days. The pulmonary reduction could be improved by aggressive respiratory therapy during the first three days after extubation from mechanical ventilator. CPAP via mask therapy appeared to be more effective and less painful than IS or DBE therapies.

Celli and colleagues (1984) randomly included 172 post-operative patients to examine the effectiveness of the three types of therapies (IPPB therapy for 15 minutes four times daily, IS therapy four times a day and deep breathing exercise 15 times daily) against the control group with no post-operative therapy. The development of PPCs was double in the control group (48%) as compared with the other three therapy groups (approximately 22%, p= less than 0.05). IPPB group had higher rate of respiratory side effects (18%, p= less than .05). Also, IS group had significant reduction in hospital stay (mean +/- SD, 8.6 +/- 3 days) as compared with control group (13 +/- 5 days). However, there were no significant differences for hospital stay in the other two groups of therapies.

Stock, Downs, Gauer, Alster and Imrey (1985), compared CPAP, IS and DBE in terms of preventing PPCs in a group of 65 post upper abdominal surgery patients. The improvement of post-operative pulmonary function was faster in the CPAP group. The incident of atelectasis after post-operative day was double in DBE group (42%) and IS group (41%) as compared with CPAP group (23%). In addition, CPAP group of therapy had less effort from the patients and minimum pain. The study clarified the importance of the type of persons who applied the respiratory therapy and the frequency of therapy.

Ricksen, Bengtsson, Soderberg, Thorden and Kvist (1986), randomly compared CPAP via mask, PEP and IS in a group of 43 post-operative patients. All groups of therapy were applied during the waking hours for 30 consecutive breaths in the first three post-operative days. The incidences of atelectasis, gas exchange difference and pulmonary function (FVC and peak expiratory flow (PEF)) have been used to compare the differences between the groups. There were no significant differences between the three groups in gas exchange and peak expiratory flow. However, there was a significant difference in the occurrence of post-surgical atelectasis in IS group (control) (six of 15 patients, p= 0.001) as compared to CPAP or PEP groups. Also, there was a significant increase (p less than 0.05) in the lung volume (FVC) in CPAP and PEP groups post therapy as compared to the IS group.

Linder, Lotz and Ahnefeld (1987), found that 12 cmH_2O of CPAP therapy applied for three hours daily in the first five post-operative days after extubation from mechanical ventilation improved the reduction of pulmonary function caused by major upper abdominal surgery. Schwiege et al. (1986), examined the benefit of IS therapy in low risk post-operative patient as compared with traditional physiotherapy only. IS therapy was applied for 5 minutes (12

times daily) for three days after surgery. There was no significant difference between the two groups in PaO_2, chest x-ray result, lung function values and clinical evaluation.

In another study by Jenkins, et al., (1989), they evaluated the difference in force vital capacity (FVC) (measured at first and fifth post-operative day) and oxygen arterial blood gas tensions (PaO_2) (measured at second and fourth post-operative day) between the three postoperative respiratory therapy regimens. The control group used self-breathing exercise and coughing, the first group used breathing exercise and coughing plus CPT and the second group used IS. The results showed no significant difference in means between the groups of therapies in FVC and PaO_2 after surgery (means FVC day one 1.9L (61% of pre-operative value), day five 2.3L (76%) and PO_2 on day two 7.3 kpa, 8.5 kpa on day four). However, the post- CABG patients were low risk patients.

A meta- analysis and systemic overview by Thomas and McIntosh (1994), evaluated the difference between four group of therapies (no therapy, IS, IPPB and DBE therapies) to prevent PCCs. 14 trials fit their inclusion criteria after searching all trials in data base information systems of MEDLINE and others health care services from 1966 to 1992. The common odds ratio (COR) for the incidence of PPCs increased significantly (more than 60%) in no therapy group as compared to IS and DBE groups of therapies. However, there was no significant difference between the three groups of therapies (COR for IS vs IPPB = 0.76%, IS vs DBE = 0.91% and IPPB vs DBE = 0.94%).

Ebeo, Benotti, Byrd, Elmaghraby and Lui (2002), evaluated the effect of bi-level positive airway pressure (BiPAP) therapy in pulmonary function and surgical atelectasis after major

abdominal surgery. BiPAP therapy was applied during the first day of surgery and pulmonary function variables (FVC and FEV_1) measured during the first three days of surgery. The result showed significant increase in FVC and FEV_1 during the first three post-operative days in BiPAP group as compared to the control (traditional post-operative care) group. Also, during same period of time measurement, SpO_2 decreased significantly in the control group. However, there was no significant difference between the groups in hospital stay or in the incidence of post pulmonary complication rate.

Post-surgical atelectasis is common after cardiac surgery and may increase the post-operative risk factors for morbidity and the length of hospital stay. Pasquina, Merlani, Granier, and Ricou (2004), investigated the efficacy of non-invasive pressure support ventilation (NIPSV) and CPAP therapy to treat or prevent post-surgical atelectasis after cardiac surgery. The duration of each therapy was 30 minutes four times daily. The setting pressure was 5 cmH_2O in the CPAP group and the pressure was adjusted to the support tidal volume to 8-10 ml/kg in NIPSV group. The result showed significant improvement ($p=0.02$) in post- surgical atelectasis radiological score rate by 60% in NIPSV group as compared to a 40% improvement in CPAP group. However, there were no differences between both groups in pulmonary function result, PaO_2, gastric distensions and hospital stay.

Muller, Olandoski, Macedo, Costantini and Guarita-Souza (2006), compared the difference in several variables (PO_2, PCO_2, SaO_2, tidal volume (TV), respiratory rate (RR) and the use of accessory muscle) between CPAP and intermittent pressure after cardiac surgery at three hours, 24 hours and 48 hours. The result showed no significant difference between both groups in arterial blood value (pO_2, pCO_2 and SaO_2, p value =0.494, 0.221 and 0.368

respectively). However, there were significant differences in TV, RR and use of accessory muscles towards intermittent pressure (p value = 0.014 and 0.001 respectively).

Romanini, et al., (2007), compared the effect of IPPB therapy with IS in a group of 40 post cardiac surgery patients.SpO_2 increased significantly after 48 hours and 72 hours (p= 0.0007 and 0.0001 respectively) in the IPPB therapy group. Also, Maximum Expiratory Pressure (EP Max) increased significantly in the IS group after 24 hours and 48 hours (p= 0.02 and p= 0.01 respectively). However, there was no significant difference between both group in respiratory rate (RR), minute volume (MV) and current volume (CV). The result above shows that the use of IPPB therapy will improve the oxygenation and IS therapy will improve the expansion of respiratory muscle.

Pulmonary function variables (such as forced vital capacity and forced expiratory volume in one second), maximal respiratory pressure and oxygen saturation has been used in a group of 36 post cardiac patients by Renault, Costa-Val, Rosseti and Houri-Neto (2009), to evaluate the difference between two single therapy (deep breathing exercise and IS) . The result shows no significant difference between the two groups of therapy. However, the two therapies were started after 24 hours of extubation from mechanical ventilation and during the 24 hours period both groups used non-invasive ventilation, which may have affected the outcomes of both therapies. The study confirmed the reduction in lung volume and inspiratory muscle strength associated with the cardiac procedure. The therapy was started in the present study immediately after the patient was extubated from mechanical ventilation.

A meta-analysis by Guimaraes, El Dib, Smith and Matos (2009), reviewed all randomized trials registered in Cochrane database, which used IS for upper abdominal surgery from the beginning of trials registrations in Cochrane control to July 2006. Seven trials from the 11 trials reviewed were included in the Meta analysis because the quality of the methodology and the prescribed therapy used in the other trials was not clear. Two from the accepted trials compare IS with Chest physiotherapy (CPT) and a total of 946 patients participated in the studies. Also, two studies compared IS with deep breathing exercises (194 participants) and the remaining three trials compared IS with no therapy provided (120 participants). All accepted trials results showed no significant effect, improvements of the lung collapse or prevention of post-surgical atelectasis in IS therapy groups compared to CPT or no therapy. The Meta analysis authors suggested to conduct a large trial containing high quality methodology to compare IS therapy with other therapies to clear the debate about IS therapy effect, especially regarding mortality.

Most of the reductions in respiratory volume and flow due to post-operative complications happened as a result of either abnormal pulmonary volume or respiratory muscle function associated with respiratory diseases, or abnormal chest wall associated with thorax or upper abdominal surgeries (Dureuil, 2002). Performing pre and post-operative strategies such as a combination of physical and medical therapies, pulmonary rehabilitation and patient mobilization will result in improved post-operative medical outcome and reduction in post-operative pulmonary complications (Sharafkhaneh, Falk, Minai & Lipson, 2008). Also, there were several special considerations, as pre-operative strategies depend on what type of patients undergo major thorax surgery (for example if the patients had chronic respiratory

disease, the type of medications and other therapies taken should be optimized before the surgery).

2.1.2 Combine therapy added chest physiotherapy (CPT):

The standard therapy for mobilization and removal of lung secretion is chest physiotherapy (CPT). CPT which consists of vibration of the chest and manual percussion has been used to remove post-operative lung secretions since the middle of the last century (Thoren, 1954). The ability of post-operative patients to remove their lungs secretions is one of the important factors for success or failure of any post-operative therapy or method. Increased lung secretions after the surgery results in decreased lung capacity, increased intra-pulmonary shunt, hypoxemia, pneumonia and increased work of breathing (Jansen et al., 1995). The effectiveness of CPT to improve lung function and reduce or prevent PPCs has been determined by several previous studies (Arens et al., 1994; Kempainen & Benditt, 2001).

Minschaert, Vincent, Ros & Kahn (1982), examined the effectiveness of IS therapy plus CPT and CPT therapy alone to treat or prevent PPCs. Respiratory rate (RR), Tidal volume (TV), VC and spirometric values were measured during the post-operative study period. The results showed IS group had faster recovery toward pre-operative respiratory volumes. The study confirmed the prevention of PPCs by combined therapy (IS plus CPT) after upper abdominal surgery. Christensen et al. (1991) examined the difference between single therapy (CPT) and two types of combined therapies (CPT plus positive expiratory pressure or CPT plus positive expiratory pressure and inspiratory resistance) in a group of 52 post-upper abdominal patients. There was no difference in PPCs occurrence between all groups of therapies except that the combined therapy groups had lower frequency of pneumonia (6%). All groups

showed decrease in lung function post-surgery. However, the combined therapy (CPT plus positive expiratory pressure and inspiratory resistance) showed the least decrease in FVC, PaO_2 and SaO_2 ($p=0.008$, $p=0.008$ and $p= 0.002$). Also, the combined therapy was considered to be the most effective therapy.

In a randomized prospective study, Larsen et al. (1994) investigated the difference between the three types of therapies applied via mask (CPAP, PEP and inspiratory resistance-positive expiratory pressure (IR-PEP)) to treat or prevent PPCs. Each therapy was applied as added to routine chest physiotherapy by a well-trained therapist. 160 post-thoracic surgery patients were assessed by chest x-ray, FVC and PaO_2. All measurements took place pre-operatively, and on the fourth and ninth days of surgery. The result showed no difference between all groups of therapy in the amount of decrease in FVC and post-operative atelectasis frequency. IR-PEP therapy had less PaO_2 decrease on day nine measurement. The previous study confirmed the usefulness and safety of applying positive pressure system with regular chest physiotherapy.

Hall, Tarala, Tapper and Hall (1996) evaluated the difference between the three types of post-operative respiratory therapy in a group of 456 patients. The participants were randomly divided into two groups depending on the risk of their operations. Single therapy (either deep breathing exercise (DBE) or IS) was used for low risk patients and combined therapy for high risk (DBE plus CPT or IS plus CPT) patients. Also, the time taken to deliver each therapy was evaluated. The combined therapy had lower rate of PPCs by 3% as compared to single therapy. However, the difference is statistically not significant ($p=0.4$) and added CPT increased the time spent for combined therapy by 30 minutes for each therapy. However, in

the previous study the frequency of CPT depended on the physiotherapist's decision and the time taken to assess the requirement for providing CPT was included in the total time spent on each patient.

Several methods or therapies (IS, CPT, CPAP and DBE) have been used after major surgery (such as upper abdominal and thoracic surgery) to improve lung volume and clear the airway secretion. Denehy, Carrol, Ntoumenopoulos and Jenkins (2001), in a group of 57 patients, compared two levels of CPAP therapy (every 15 or 30 minutes four times a day) added to regular physiotherapy techniques (DBE, maximum inspiratory manoeuvre and deep breathing and cough expectoration) with regular physiotherapy only twice a day. FRC, VC, SpO_2, incidence of PPCs and hospital stay were measured in all groups. All treatment was applied in the first three post-operative days. The results showed no significant difference between all groups in lung function variable (FRC and VC). CPAP therapy for 30 minutes had lower occurrence of PPCs (6%) as compared with other groups (CPAP therapy every 15 minutes (11%) and control group (22%). There was no significant difference in hospital stay between all groups. However, patients who developed PPCs had significant increase in hospital stay ($p=0.021$).

A randomized prospective study in a group of 24 patients by Borghi-Silva et al. (2005), evaluated the difference between combined therapy and single therapy to improve the pulmonary function and inspiratory muscle strength after cardiac surgery. Spirometer was used to measure pulmonary function and maximal inspiratory pressure was used to measure inspiratory muscle strength. The result shows significant reduction in pulmonary function in all variables (such as peak flow) in single group, while only one variable (vital capacity) in

combined group had significant reduction ($p<0.05$). The maximal inspiratory pressure had significant reduction in single group therapy. The study confirmed the reduction in pulmonary function variables and inspiratory muscle strength associated with cardiac surgery procedures. It addressed the requirement of combined therapy to correct these reductions.

In another study by Haesfener, Ferreira, Barreto, Arena and Dall'Ago (2008), it examined the effect of combined IS with EPAP to treat PPCs after cardiac surgery. The result showed significant difference in maximal respiratory pressure, force vital capacity (FVC), force expiratory volume in one second (FEV_1) and 6 minutes' walk test in the combined group, when compared with the control group ($p< 0.001$). The outcome at one month was better than the one week outcome in the combined group compared to the control group. The control group had higher radiological injury score at one week when compared with the combine group ($p<0.004$) while PPCs reduced in the combined group. However, the total number of participants in the study was only 34 patients (17 in each group).

Forti, Ike, Barbalho-Moulim, Rasera and Costa (2009) evaluated the differences between CPT therapy alone and combined with transcutaneous electrical diaphragmatic stimulation (TEDS) in respiratory function and respiratory muscle expansion. Forty four obese female patients after gastric bypass surgery were included in the study and they found no difference in respiratory volume or flow between the two groups' pre-operatively, after fifteen days or after thirty days post-operatively, except that the expiratory muscle exhalation was better in the combined therapy group. However, the study confirmed the reductions in respiratory volume or flow after major surgery.

2.1.3 Prevention of post-operative pulmonary complication (PPCs):

The prevention of post-operative pulmonary complications is one of the most important factors towards improving the surgical outcomes, improving patient morbidity and reducing the length of hospital stay. Meyers, Lembeck, O'Kane and Baue (1975) found out that the lung function variables (VC, FEV_1, RV and FVC) decreased after upper abdominal surgery. The maximum decrease occurred during the first 48 hours after the surgery. However, the lung function values started to recover gradually by the fifth day toward the pre-operative lung function values. When there is a decrease in FRC after surgery by more than 40% as compared to pre-operative values, most probably the patient will develop PPCs. Moreover, IPPB had equal effectiveness in lung function value as compared to other therapies.

Hall, Tarala, Harris, Tapper and Christiansen (1991), examined the effectiveness of IS and CPT to prevent PPCs after abdominal surgery in a group of 876 patients. Results showed no significant difference between the two groups in the occurrence of PPCs (IS group 68 of 431(15.8%) and CPT group 68 of 445 (15.3%). Also, there was no difference between both groups in hospital stay, chest x-ray, sputum pathogens and PaO_2.

In another study by Chumillas, Ponce, Delgado, Viciano and Mateu (1998), investigated the benefit of respiratory physiotherapy in the prevention of PPCs in a randomized control trial. The result showed that the incidence of PPCs was less in the treatment group (7.5%) than control group (19.5%). There was a significant association between the increase in the risk of PPCs and a history of chronic respiratory disease ($p=0.02$).The incidence of PPCs increased significantly when the surgical period took more than 120 minutes ($p=0.03$). The study

confirmed the reduction in post-operative pulmonary function values without significant difference between both groups.

Pasquine et al. (2003), reviewed 13 trials and evaluated the effectiveness of CPAP, IS and IPPB therapies to prevent post-operative pulmonary complications (PPCs) after cardiac surgery. No significant benefit was found with any of the three therapies. However, some of the trials had no control group and others had low quality methodology. The incidence of post-operative atelectasis was 15-98% across all trials. The incidence of post-operative chest infection was 0-20% and there was 37-72% reduction in VC values as compared to pre-operative values. The reduction of post-operative FEV1 values ranged from 34-72%. The average cost of CPAP therapy for each patient was 32 US dollars or 27 Euros.

A systemic review by Lawrence, Cornell and Smetana (2006), searched MEDLINE and other available publications from 1980 to 2005, to evaluate the evidence that supports the use of intervention therapy to prevent or reduce PPCs. They found out that there was strong evidence to support the use of lung expansion intervention therapies such as IS, DBE and CPAP. However, the evidence supporting pre operation interventions (for example smoking cessation, epidural anesthesia, laparoscopic or open operations) were not clear. The importance of PPCs in term of mortality, hospital stay and morbidity were identified clearly.

Moreover, Freitas and colleagues (2007) reviewed several scientific web sites (from 1980 to 2004) to evaluate the benefit of IS therapy to prevent post cardiac surgery pulmonary complication. The results showed no significant difference between IS and other types of therapy (such as CPAP, IPPB, BiPAP or pre-operative patient education) to prevent or reduce

PPCs, especially atelectasis and pneumonia. However, arterial oxygenation and the pulmonary function in IS group was not as good as other groups of therapies. Only four trials fit the inclusive criteria due to the requirement of high quality type methodology. Also, they suggested performing a future study with high quality methodology and power to clarify the benefit of IS therapy.

There were general considerations such as smoking must be stopped at least 6 to 12 weeks before the surgery, as smoking increased the post-operative pulmonary complications (Warner, et al., 1989). When the patient requires pulmonary or cardiac rehabilitation before the surgery, he or she should be enrolled in this programme which would reduce the post-operative complications (Ries, Make & Reilly, 2008). One of the very important factors to reduce the post-operative pulmonary complications is the management of the complications during the operation such as the anaesthesia, the mechanical ventilation and the medication management (Naunheim, et al., 2006). The successful management of post-operative period (such as early extubation and mobilization, control of post-operative pain, infection and bleeding, prevention of respiratory failure and prolonged mechanical ventilation and early application of post-operative respiratory therapy management) will result in preventing post-operative lung volume reduction and post-surgical atelectasis.

Post-operative morbidity and mortality usually occurred as a result of pulmonary complications associated with major thoracic or upper abdominal surgical procedures. Understanding post-operative pulmonary morbidity risk factors will decrease or prevent the occurrence of these problems. The mean potential predictors for PPCs are the type of surgical procedure, smoking, age and patient's diet.

However, when the surgical procedures are necessary, the importance of contra-indication disappears. At least 8 weeks before surgery, patients are required to quit cigarette smoking. Also, cough and lung expansion training techniques should start one or two days before the surgical procedure. However, sometimes the effectiveness of quitting smoking and patient diet improvement cannot be judged due to the shortage of pre-operative assessment (Rezaiguia & Jayr, 1996).

General anaesthesia affects the respiratory functions more than regional anaesthesia. Therefore, the expectation of respiratory function reduction after CABG is high, because CABG procedures always use general anaesthesia. The type and the period of anaesthesia are one of the main causes of early PPCs. Post-operative morbidity delay is often associated with the surgical procedures. The post-operative therapy is advised to be continued for three to five days after major thoracic surgery. The study found equal effectiveness of the three respiratory therapy techniques (CPT, IS and CPAP). IPPB therapy has no advantage as compared with other therapies. The most practical therapy available to clear airway secretion is CPT and IS therapies. However, CPAP via mask therapy has additional advantage of post-operative atelectasis improvement (Rezaiguia & Jayr, 1996).

According to Saxena, Luthra, Dhaliwal, Rana and Behera (2007), the reductions in pulmonary function after cardiac surgery occurred immediately and gradually recovered close to pre-operative values within three months. Gosselink *et al.,* (2000), examined the effect of added IS therapy to regular chest physiotherapy (huffing, coughing and breathing exercises) in a group of 67 patients post thoracic surgery. Chest radiograph, pulmonary function, hospital stay, body temperature and white blood cell count were measured to compare the

two groups. The result showed significant decrease (55%) in post-operative pulmonary function (FVC and FEV1) values as compared with pre-operative values in both groups. The pulmonary values were improved significantly (p=0.01) in both groups after the surgery. However, it required more than three weeks to recover close to pre-operative values (Gosselink, et al., 2000).

The incidence of post-surgical atelectasis was similar (approximately 12% in each group) as shown in chest radiograph result. The incidence of PPCs (defined as development of atelectasis, increase in count of white blood cell and raised body temperature) occurred in four patients in both groups. PPCs and hospital stay will not be decreased by adding IS to regular chest physiotherapy as compared with chest physiotherapy alone. However, high risk patients may benefit from the combined therapy.

Prevention of post cardiac surgery pulmonary complications by any interventional respiratory physiotherapy is still not clarified by any of the previous studies and trials. The requirement of a large clinical trial with no intervention control group is needed to clarify the actual beneficial use of intervention therapies to prevent PPCs.

2.1.4 Pre-operative respiratory care:

Risk of post-operative pulmonary complication (PPCs) should be considered before the cardiac surgery to reduce the risk factors after the surgery, which includes the type of procedure and the patient pre-morbid conditions. The plan for reducing the possibility of PPCs must start before the surgery and continue until the patient recovers after the surgery (Myrianthefs & Batistaki, 2007).

Yanez-Brage and colleagues (2009) examined the effectiveness of pre-operative traditional respiratory therapy (such as IS, DBE and coughing manoeuvre) in reducing the occurrence of PPCs as compared to no pre-operative treatment group. 159 post CABG patients participated in the study and both groups were similar in age and cigarette smoking habits. The result showed that the incidence of post-operative atelectasis was significantly less in patients who received pre-operative therapy as compared to no therapy group (17%, 36%, p=0.01 respectively). The previous study confirmed the benefit of pre-operative traditional respiratory therapy.

Pre-operative pulmonary assessment and management are very important components after upper abdominal or cardiac surgery for two reasons. First, medical staff should be able to identify patients with high risk factors. Second, before the surgical procedure, any reversible component should be eliminated or treated. All patients undergoing cardiac surgery or upper abdominal surgery are at risk of post-operative pulmonary complications (PPCs). However, those with respiratory system diseases are at increased risk. Specifically, the risk is post-operative morbidity and mortality due to respiratory complications (Baudouin, 2003).

A randomized control trial by Arthur, Daniels, McKelvie, Hirsh and Rush (2000), evaluated the efficacy of pre-operative care (such as exercise twice a day) in low risk CABG patients to prevent PPCs. The hospital stay decreased significantly in pre-operative care group by one day (p= 0.001). However, there was no significant difference in mortality rates between the two groups.

Another study by Hulzebos et al. (2006), evaluated the efficacy of pre-operative respiratory care management to prevent the incidence of PPCs in high risk patients post CABG. The result showed PPCs occurred 16% more in those with no pre-operative care, as compared to pre-operative care group (48/137 (35%) patients and 25/139 (18%) patients respectively). The hospital stay decreased in pre-operative care group (the median 7 days in the pre-operative care group and 8 days in the other group).

The incidence of respiratory problems as a result of anaesthetic complications have been noted frequently after major surgery. While the leading cause of mortality after anaesthesia and surgery is pre-operative cardiac morbidity (Rodrigues et al., 2011), there was a high percentage (<50%) of deaths and comas relating to anaesthesia due to respiratory problems (Pedersen, 1994). However, the previous study reporting anaesthetic-related respiratory complications included all problems affecting the respiratory system in the hospital wards and post-operative respiratory failure.

Pulmonary complications in general terms represent post-operative pulmonary normal changes. The range of complications is large and can range from subclinical atelectasis, to difficulty in weaning a patient from mechanical ventilation, to post-operative respiratory failure. Most of the patients experience some changes in pulmonary function post-operatively and 6 to10 percent of all post-operative patients with normal lung function may develop PPCs (Kanat et al, 2007). Patients with pre-operative pulmonary disease have a higher risk of mortality (15.6 percent) than those without pulmonary disease (1.6 percent) and may need post-operative mechanical ventilation 20 times more often than normal patients (Pappalardo et al., 2004).

Cardiac surgery or upper abdominal surgery results in abnormal pulmonary function and the respiratory changes are best described as primary, secondary, and tertiary. The primary changes are those of the respiratory mechanics. The secondary changes represent gas exchange abnormalities. The tertiary changes are those relating to respiratory mechanical dysfunction (Imberger, et al., 2010; Rodrigues, et al., 2011).

To maintain normal minute ventilation during or after the surgery, when the tidal volume is small, requires an increase in respiratory rate which will lead to reduction in inspiratory capacity (IC) and vital capacity (VC). The latter decrease will cause a reduction of 40 percent in the normal pre-operative pulmonary function values immediately after upper abdominal surgery and is expected to decrease more after cardiac surgery. Thirty percent reduction occurred in VC value after one week of upper abdominal surgery and required at least three weeks for full recovery. In addition, the reduction in functional residual capacity (FRC) occurs slightly later, approximately 12-16 hours after the surgery. The lowest point of reduction of FRC after upper abdominal surgery reached 70 percent at one day post-operatively. However, it becomes normal gradually over seven to ten days (Ferreyra, Long & Ranieri, 2009).

There was a reduction in post-operative measurement for maximum inspiratory and expiratory flow rates. The abnormalities in gas exchange happen in two phases. The first occurs immediately after surgery, and ends within two hours. The second phase occurs later in the post-operative period due to respiratory mechanical dysfunction (Bigler, 2003).

The limitations in IC restrict the patient's capability to cough effectively. The small lung volumes relating to the reduction in FRC are very important as it can cause greater effect on oxygenation. The reduced FRC interrupts the closing capacity, or the volume at which small airways close, leading to the occurrence of post- surgical atelectasis. Mild atelectasis is caused by the occurrence of cough, increase in alveolar-arterial gradient or mild fever (Bernstein & Deshpande, 2008). For example, the percentages of these occurrences range from 25 to 75% after thoracic and upper abdominal surgery (Andrejaitiene, Sirvinskas, & Bolys, 2004). This type of atelectasis can be seen clearly on chest roentgenogram recognized by loss of segmental, lobar or often lung volume. However, the decrease in surfactant activity assists in sustaining airway closure (Hedenstierna & Rothen, 2000).

Post-operative major atelectasis may cause right to left shunting of blood and abnormal ventilation/perfusion (V/Q) mismatch. There was a correlation between hypoxemia and reduction in FRC and the lowest values occurred during the first twenty four hours after the surgery (Craig, 1981). The reasons for these post-operative pulmonary changes explained by Treschan and colleagues (2012) were found in the immediate post-operative period. There was a significant reduction in normal lung volume without a change in minute volume (the total lung volume in a minute). Also, there was a decrease in pulmonary lung function values (vital capacity and force expiratory volume in one second) and increase in alveolar-arterial gradient. Post-operative atelectasis appeared on chest radiograph result in 60% of the participants.

More importantly, the reduction in diaphragmatic activity after surgery was associated with a shift in breathing pattern, which may lead to an increase in the work of breathing. These

changes may return towards normal value after the first post-operative day. Another study suggested the reason for diaphragmatic dysfunction was related to the type of anaesthetic drugs used during the surgery (due to inhibitory reflexes to phrenic nerve activity) and was not due to the surgical procedure (Groeben, 2006).

The midline incision is usually associated with higher incidence of post-operative pulmonary complication (such as decrease in pulmonary function and hypoxemia) as compared to other types of incision. Increase in the period of surgery is associated with increase in the duration of anaesthetic drugs that results in greater reduction in FRC. It seems that a greater reduction in FRC is correlated with an increase in length of operation. The risk of FRC reduction was more when the duration of operation was more than four hours (Tavolaro, et al., 2010). However, when the patient had pre-operative cardiac morbidity, the risk started after three hours of operation (Moreno, et al., 2011).

The main factor responsible for the increase of anaesthetics after surgery is post-operative pain and its management and this becomes a major problem for the treating physician. Sufficient relief may be associated with pulmonary depression due to sedatives, opioids and other analgesics which may cause central effect, which may lead to a decrease in respiratory rate and lung volume. Insufficient relief of post-operative pain may lead to rapid and shallow breathing, which will result in patient refusing to do lung expansion therapy. There will be inadequate cough manoeuvre to remove post-operative pulmonary secretion (Qaseem, et al., 2006). However, post-operative pain is not considered a key mechanism for post-operative pulmonary dysfunction (Veering, 2003).

2.1.4.1. Patient factors

The accurate management of pre-operative patient risk factors is one of the most important factors that affect the surgical outcome. The patient's pre-existing conditions such as airway narrowing or obstruction can be treated by bronchodilator therapy or CPT therapy in case of mucus plug. However, post-operative respiratory deterioration is difficult to recognize in the early phases of compromise (Duggan & Kavanagh, 2010).

Pre-operative assessment of the patient's clinical signs and symtoms, physical examination and medical history are very important. When the surgical patient is obese, they may require short term diet schedule and in case of obstructive sleep apnea, they may require a short period of nasal CPAP before the surgery (Smetana, 1999). If the patient loses weight, he or she may require nutritional repletion before the surgery, especially cardiac surgery or major surgery (Howard & Ashley, 2003).

Zoremba, Dette, Gerlach, Wolf and Wulf (2009), evaluated the effectiveness of post-operative intervention therapy to treat PPCs (especially atelectasis) for post-operative obese patients. They used SpO_2 and inspiratory lung function measurements to compare the group of therapy or no therapy. There was a significant improvement ($p= 0.0001$) in therapy group in lung function on the first post-operative day and a reduction in hospital stay.

One of the most important reversible patient factors is smoking. Stopping smoking before cardiac surgery is necessary and requires six to eight weeks to benefit (Rezaiguia & Jayr, 1996). Also, the high level of carbon monoxide in the blood of a smoker affects the measurement of oxyhemoglobin saturation, especially with pulse oximetry monitoring

(Arunabh & Feinsilver, 2000). However, it requires at least three days for carbon monoxide level to return to normal level after patient quits smoking. As a result of quitting smoking the mucus level increases in the first week and after that reduces to the normal level (Warner, 2006).

The patient with chest or other types of infections should be treated by antibiotic therapy and repeated laboratory measurement and chest radiographic results should be normal before the surgery. The resolution of the reversible patient factors before cardiac surgery will lead to better surgical outcomes and may reduce post-operative pulmonary complications. Usually it takes six to eight weeks as preparation time for elective cardiac surgery as standard care in cardiac surgery department, such as in the hospital where this study took place. However, in case of emergency, and requirement of immediate cardiac surgery, patient preparation cannot be done.

2.1.4.2. Elderly patients:

The incidence of PPCs is common in elderly post-operative patients and may lead to increased post-operative mortality, morbidity and lounger hospital stay. Cardiac complication risk factors can be divided into two main groups. The first is risk factors relating to the patient such as smoking, chronic pulmonary disease, obesity or significant loss of body weight, abnormal chest x-ray and renal deficiency. The second is risk factors related to surgical procedure such as the site of the surgery, the type of the surgery, particularly if high risk, the duration of the surgery which takes more than three hours, and general anaesthesia. However, when elderly patients are well prepared for the surgery, the age risk factor becomes

minor. Post-operative pulmonary complication for elderly patient can be reduced by pre-operative respiratory care (such as deep breathing exercise and IS) and epidural local anaesthetics during the surgical procedure (Smetana, 2003).

Another study by Dronkers and colleagues (2008), investigated the effectiveness of pre and post-operative chest physiotherapy (CPT) to prevent PPCs in elderly patients as compared to post-operative CPT only. Post-surgical atelectasis rates were significantly decreased after cardiac surgery in the pre and post-operative group. There was no significant difference in pneumonia rate in both groups.

2.1.4.3. Anaesthetic Factors:

The management of anaesthetic factors during and after the surgery is potentially important to reduce or to prevent PPCs, especially mechanical ventilation and anaesthetic medication factors. Patients with airway diseases often have increased alveolar dead space, especially elderly patients. Usually they require large tidal volume with slow respiratory rate to solve this problem during the mechanical ventilation period. Also, anaesthetic physicians during the surgery use a nomogram to verify ventilator requirement and end-tidal PCO_2 monitor to manage hypoventilation status (Hedenstierna & Sandhagen, 2006). However, the requirement of ventilatory support during the operation may increase up to 25% more than the expected ventilation for the patient with pulmonary disease (Dueck, 2006).

The use of short-acting anaesthetic medication may decrease the risk of anaesthetic factors and may decrease the respiratory dysfunction related to the surgical procedure. Management and selection of accurate anaesthetic drugs (such as alfentanil, midazolam and fentanyl) are

very important factor to reduce the incidence of hypoxemia, hypoventilation, apnea and hypoxic ventilator drive (Padmanabhan, Leslie, Eer, Maruff & Silbert, 2009). Another important factor is the careful plan for analgesia therapy after the surgery, during the recovery period and in the critical care unit and hospital ward (Gruber & Tschernko, 2003).

2.1.4.4. Surgical Factors:

Post-operative pulmonary complications (PPCs) are related to the type of thoracic surgery and the location of the surgical incision. The specific reason causing pulmonary damage is not clearly known yet. However, it is most likely to happen during the surgical procedure. Several factors are associated with the occurrence of pulmonary damage during the cardiac surgery procedure, such as the type of anaesthesia, the type of mechanical ventilation, the duration of the surgery and the type of the surgery (Baudouin, 2003).

O'Donohue (1992) defined pulmonary complications related to surgical procedures as any abnormality that occurs to the chest after the surgical procedures, which creates particular dysfunction or disease that is medically significant, and which negatively influences the medical method. As the occurrence of pulmonary complications depends on several factors mentioned above, there was no specific definition of post-operative pulmonary complications. However, several authors (Zibrak & O'Donnell 1993; Kips, 1997; Doyle, 1999; Weissman 2004) used the definition of post-operative pulmonary complications to identify the pulmonary problems such as atelectasis, pneumonia, high fever, pleural effusions, pulmonary oedema and pneumothorax. In addition, the greater alteration of

pulmonary function by cardiac surgery procedure will result in increase in post-operative pulmonary complications.

2.1.4.5. Cardiac surgery procedures:

The substantive study of the Duke University group recognized that PCI was better than CABG in patients with a single vessel disease, other than proximal left anterior descending (LAD) artery stenosis, and CABG was better than PCI in patients with multivessel disease, or proximal LAD artery stenosis. Patients with double vessel disease, or an isolated proximal LAD artery stenosis, had similar results with PCI and CABG. The final decision on the technique of revascularization depends on clinical variables, for example the characteristics of the stenosis, the patient's ventricular function, the age of the patient, and related co morbidities (Pretre and Turina, 2001).

- CABG Technique

Coronary artery bypass graft (CABG) surgery is performed to go around a part of an artery that has been narrowed or blocked by plaque build-up (atherosclerosis). The blocked part of the artery is bypassed using a blood vessel taken from elsewhere in the body (usually the chest or leg). Blood is transmitted through the new blood vessel, restoring blood flow to the affected part of the heart muscle. CABG is a common treatment for coronary artery disease (Palmerini, et al., 2012).

❖ General cardiac surgery procedures

These procedures are the same as the general cardiac surgery procedures where the present study took place.

- All open-heart procedures are done with Cardiopulmonary bypass (CPB) and under general anaesthesia.
- The patient is put in supine position (or right thoriacotomy in certain cases) and exposed parts of the body are painted with povidone iodine, which is left to dry for two minute.
- The patient is draped and a median sternotomy performed.
- Heparin is given and the ascending aorta and auricle of the right atrium are cannulated. The CPB is started after the activated coagulation time has been checked.
- CPB is only started after making sure that every member of the team is ready and the saphenous vein (in case of coronary artery bypass grafting) is usable.
- Under moderate hypothermia, the operation on the coronary vessels and/or valve is performed.
- The induction of cardiac standstill is achieved by delivering ante- and/or retrograde cardioplegia either with warm or cold blood cardioplegia.
- Before finishing the CPB, the patient is rewarmed, the heart debubbled and surgical haemostasis ensured. Gradually, the CPB is discontinued with varying amounts of inotropic drugs and/ or mechanical support.

- When indicated, pacemaker wires are applied to the right ventricle and/or right atrium. After administration of protamine sulphate, the cannulae are removed and the haemostasis controlled. The drains are introduced, the number of drain vary according to the preference of the surgeon.
- After a swab count, the wound is closed in layers, the sternum with steel wires, the subcutaneous tissues with vicryl sutures and finally the skin with a running mono 3-0 suture.
- The patient is transferred to his or her bed and moved to the intensive care unit for further treatment.

Coronary artery bypass grafting procedure (CABG)

In addition to the general cardiac surgery procedures in a CABG operation, it is important to prepare graft material. This graft material can be saphenous veins, IMA arteries or radial artery.

- The graft material is taken before extracorporeal circulation is started.
- Once on bypass, the sites for the distal anastomoses are identified and after cardioplegia, the coronary vessels are opened.
- Distal anastomoses are done with prolene 8-0 or 7-0 depending on the preference of the surgeon.
- Proximal anastomoses are usually done with prolene 6-0. After completion of the revascularisation, the extracorporeal circulation is weaned, guided by BP, CVP, ECG, etc. and eventually stopped.

2.2 Respiratory physiotherapy devices:

Respiratory physiotherapy devices used with different types of methods or therapies have increased dramatically in the last two decades. Some of these devices are used to improve the pulmonary function deterioration, and others are used to remove the mucus from lung airway. Also, some of these devices in recent years have been used as alternative methods to the traditional respiratory physiotherapy methods. There were several types of application for these devices. Some required a therapist to apply and others allowed the patients to apply themselves. There have been several benefits of these devices to improved patient compliance, ease of use, full control of the therapy and independent application.

These devices are IS, CPAP, CPT, Flutter, positive expiratory pressure, oral high frequency oscillation, high frequency chest wall oscillation, intra-pulmonary percussive ventilation and Acapella and Cornet. These have different effectiveness and there are difficult uses for each of these respiratory devices. The present study evaluated the effectiveness of three of them (IS, CPAP and CPT) only. It is a challenge to the therapist to choose the most effective therapy or device for each patient in order to achieve the highest daily compliance (Hristara-Papadopoulou, Tsanakas, Diomou & Papadopoulou, 2008).

2.3 Functional anatomy and physiology of the pulmonary system:

The respiratory system is made up of cells, tissues and organs. It works with the cardiovascular system, primarily to exchange oxygen and carbon dioxide between the atmosphere and the cells of the body. The process of respiration involves specialized structures that perform complex functions. The respiratory system must protect itself against inhaled contaminants. It must condition inspired gas, moving it in and out of the lungs with

minimum work. The respiratory system must expose gases to blood to assure rapid and efficient exchange. It must respond and adapt to changing conditions within the body.

The nasal cavity (the space within the nose) is separated medially by a nasal septum and the palate separates it from the oral cavity. The nasal cavity is lined with a mucosa which warms, filters and moistens incoming air. The mucosa also contains receptors for sense of smell. The ducts of the paranasal sinuses and nasolacrimal drain into the nasal cavity (Van Cauwenberge, Sys, De Bleder & Watelet, 2004).

The pharynx (throat) is consists of oropharynx, laryngopharynx and nasopharynx. The parts of the pharynx have both respiratory and digestive functions except the nasopharynx which is only a part of the respiratory system. Also, the pharynx includes tonsils, which are part of the body's defence system (Matsuo & Palmer, 2008).

The larynx (voice box) is a cartilaginous structure and it includes the thyroid cartilage (Adam's apple). The pharynx and the trachea are connected by the larynx. The laryngeal opening (glottis) is covered by the epiglottis. During swallowing, the epiglottis prevents entry of drink or food inside the pulmonary airway. Also, the larynx includes the vocal cords, which produces sounds used in speech (Noordzii & Ossoff, 2006).

The trachea (windpipe) extends from larynx to the main bronchi. The trachea is a smooth muscle pipe lined with a ciliated mucosa. It is contains C-shaped cartilage rings to keep the trachea pipe open and unbreakable. In addition, the right and left main bronchi develop from subdivision of the trachea (Epstein, 2005).

The lungs are combined of two organs close to the mediastinum in the thoracic cavity. It is covered with visceral pleura and the thorax wall is lined with parietal pleura. Pleural secretions decrease resistance during breathing. The lungs are mainly elastic tissue combined with passageways of the respiratory tree. The smallest passageways end in clusters of alveoli. Each lung is divided into smaller anatomic units called lobes. The right lung has upper, middle, and lower lobes. The lobes are divided into segments according to the branches of the tracheobronchial tree. The bronchopulmonary segments are subdivided into secondary lobules. Secondary lobules contain clusters of three to five terminal bronchioles.

The conducting system includes all respiratory airways from the nasal cavity to the smallest bronchioles. They conduct inspired air to and from the lungs. Respiratory bronchioles contain alveolar ducts and air sacs called alveoli. The alveoli have thin walls used for gas exchanges during pulmonary capillary blood transfers (Wilkins &Wehrman, 2009).

The thorax is protected by the rib cage, the thoracic vertebrae, and the sternum. It includes the lungs, heart, great vessels, esophagus and trachea. The thorax has a large base, with the diaphragm below and a small opening at the top. The opening called the operculum is surrounded by the first ribs and the upper section of the sternum. The thorax contains three main spaces which contains the major cardiopulmonary organs. These spaces are the mediastinum and the left and right pleural cavities. The mediastinum is located in the centre of the thoracic cavity and which include the heart, great vessels of the cardiopulmonary system, trachea and the esophagus. The left and right pleural cavities include the lungs.

The thoracic cage surrounds the thoracic spaces for two reasons. First, the major organs inside the thorax are protected by bony structures. Second, the thoracic bones and muscles interact to alter the cage volume. This action creates the pressures differences required to cause gas exchange inside the lungs (Scanlan, Spearman & Sheldon, 1995).

The mediastinum is the central section of the chest. It separates the left and right pleural cavities and divides the thorax vertically. Thoracic bones include the thoracic vertebrae, the sternum and the ribs and the costal cartilages. These bony structures provide support and protection to the thoracic viscera. They serve as points of origin and insertion for the respiratory muscles. The twelve thoracic vertebrae share a common structure with the entire vertebral column.

The sternum is a dagger-shaped bony structure, in the median line, at the front of the chest. The sternum works as the point of attachment for respiratory muscles and the costal cartilages. It also provides protection for the underlying organs. Corresponding to the twelve thoracic vertebrae, are twelve pairs of ribs.

The first rib moves slightly, raising and lowering the sternum. Its small motion increases the anteroposterior (AP) diameter of the chest. This action is not used during normal breathing. It becomes important under conditions that require increased ventilation, such as exercise. The six vertebrosternal ribs play an important role in ventilation. Ribs eleven and twelve do not participate in changing the contour of the chest, but act as muscular insertion points (Scanlan, Spearman & Sheldon, 1995).

Several muscles of the thorax and abdomen contribute to the movement of gas into and out of the lungs. These muscles are divided into the main and the accessory muscles of ventilation. The diaphragm and intercostal muscles are the main muscles of ventilation. They are active during both quiet breathing and exercise. The diaphragm is shaped like a dome and accounts for about 75% of the change in lung volume during normal inhalation. The ability of the diaphragm to change lung volume is altered in the presence of obstructive or restrictive lung disease. The accessory muscles of ventilation assist the diaphragm and intercostal under conditions of increased ventilatory demand. The intercostal muscles consist of two sets of fibers located between each rib pair (the external intercostal muscles and the internal intercostal muscles) (Falminiano & Celli, 2001).

The pulmonary circulation originates from the right side of the heart. Poorly oxygenated mixed venous blood is delivered to the lungs through the pulmonary artery. The main pulmonary artery exits from the heart and passes superiorly. The pulmonary artery divides into right and left pulmonary arteries. The pulmonary arteries accompany the right and left mainstem bronchi. This symmetry continues through all the divisions into the distal air spaces. Pulmonary arterioles extend to the terminal lung units. The arterioles subdivide into a bed of alveolar capillaries. The alveolar capillaries provide a large surface area to exchange oxygen and carbon dioxide with the alveoli.

Breathing is the movement of air in and out the lungs. The contraction of inspiratory muscles causes a decrease in intrapulmonary pressure, which results in the forced entry of outside air into the lungs (normal inhalation). Lung recoil or the relaxation of inspiratory muscles causes an increase in intrapulmonary pressure, which results in the forced exit of air inside the lungs

(normal exhalation). Lung expansion is influenced by the amount of surfactant in the alveoli and the presence of fluid in the pleural cavity (Wilkins &Wehrman, 2009).

2.4 Pulmonary function testing (PFT):

A pulmonary function test is an important tool in the assessment of patients with suspected or known respiratory disease. PFT is a main phase in assessing the functional status of the lungs as it relates to: air volume or how fast the air in the lungs can be moved in and out; how stiff are the lungs and chest wall and how well the gases are passing through the air sacs of the lungs. It is also important in the evaluation of patients prior to surgery and its use in screening for the presence of obstructive and restrictive diseases as well as documenting the effectiveness of therapeutic intervention. Interpretation of the PFT results requires knowledge of normal values and appearance of flow volume curves, combined with the patient's clinical history and presentation which are used to diagnose respiratory disorders.

2.4.1. PFT definition:

Pulmonary function tests determine how much air the lungs can hold, how quickly the air can move in and out of the lungs, and how well the lungs put oxygen into and remove carbon dioxide from the blood. The primary purpose of PFT measurements is to identify the severity of pulmonary impairment. Pulmonary function testing has therapeutic and diagnostic roles and aids clinicians in answering some general questions about patients with pulmonary diseases (Manoharan, Swaminathan, 2009; Brazzale, Upward & Pretto, 2010).

Pulmonary function tests are normally performed by a specialist technician. PFT plays a significant role in modern health care. It is used to assess the integrated function of the

structures that comprise the thoracic and pulmonary system. This structure includes lungs, air passages, thoracic and abdominal structures that surround the lungs. Dysfunction of one or more of the structural components can cause measurable abnormalities in pulmonary function. Disorders of respiratory system are reduced ability to move air inside and outside of the lungs, because of airway resistance problems, poor compliance of pulmonary or thoracic structures and disorders of gas exchange within the lungs (American Thoracic Society (ATS): Standardization of spirometry update, 1995).

2.4.2. Indications for carrying out lung function/pulmonary function tests:

The indications for doing PFT are dyspnea, persistent cough, or sustained sputum for more than two weeks. When suspected diseases of the bronchial airways, the lung, the heart, the thorax or the vertebral column. Also, PFT is used to investigate other respiratory diseases such as bronchial hyperresponsiveness or allergen specific sensitisation of the airways (provocation). In addition, for the therapy checks in bronchial pulmonary disease, social medical reports, pre and post-surgery to check risk of anaesthesia and reports in occupational medicine (ATS: Standardization of spirometry update, 1995).

Three factors should be considered before performing PFT measurements to ensure the accuracy and reliability of PFT measurements. First, patient should have acceptance of nose clip and mouth piece, maximum motivation is required for the patient to get reliable results and measurement should be in sitting position. Second, technologist or technician should have knowledge in routine operation of the machine, detailed and comprehensible instruction to the patient before measurement by the technician as well as reliable and motivating

instruction to the patient during the measurement. Third, the treating doctor should have knowledge of the anatomy of the respiratory tract, of the lungs and its neighboring organs, knowledge of physiology and pathophysiology of breathing and interpretation of parameters related to the physiology of the lung (AARC: Clinical Practice Guideline: Spirometry update, 1996; ATS: Standardization of spirometry update, 1995).

Complete pulmonary function test consists of three major tests spirometry, body plethysmography and diffusing lung capacity for carbon monoxide.

First, spirometry is a regular and effective diagnostic test that can be simply performed outside the PFT lab at the clinic or other room inside the hospital. It measures the volume of air inhaled or exhaled by the patient as a function of time. Spirometry is the most reliable way to differentiate chronic obstructive pulmonary disease (COPD) and asthma. Spirometry results highly associate with morbidity and normal life activity. The test also affects decisions about individual patients, including the nature of the defect, its severity, and the response to therapy. Spirometry informs the treating physician, if the patient's lungs are functioning normally, through different breathing manoeuvres (Smith et al., 2010).

Common spirometry measurements include forced vital capacity (FVC), which can be explained as maximum volume of air that can be exhaled during a forced manoeuvre. The volume exhaled in the first second of maximal expiration after a maximal inspiration is called Forced expired volume in one second (FEV_1). This is a measure of how fast the lungs can be emptied. Also, ratio of FEV_1/FVC which is FEV_1, expressed as a percentage of the FVC, gives a clinically useful index of airflow limitation. The ratio FEV_1/FVC is between 70% and 80% in normal adults; a value less than 70% indicates airflow limitation and the possibility of

COPD. However, FEV_1/FVC ratio decreases with increasing age, presumably because of changes in the elastic properties of the lung. Older healthy adults may have FEV_1/FVC ratios in the 65% to 70% range (Silverman et al., 2007).

There are three types of forces expiratory flow (FEF) rates measure during the spirometery measurements:

1. FEF 25%-75% (MMEF) - The average expiratory flow rate over the middle 50% of the FVC volume. Formerly called the maximal mid-expiratory flow (MMEF), expressed in liters/second. The FEF 25-75% measures expiratory flow rates at a later point in the manoeuvre. The accuracy of the result is slightly less effort-dependent (ATS: Standardization of spirometry update, 1995).
2. FEF 50%/FIF 50%- the flow volume (FV) loop is extremely useful in diagnosing large airway abnormalities, comparison of expiratory and inspiratory flow at 50% of the FVC helps determine the site of obstruction. In healthy patients, the ratio of FEF 50% to FIF 50% is approximately 1.0 or slightly less. Fixed large airway obstruction causes equally reduced flows at 50% of the VC during inspiration and expiration. Variable extrathoracic obstruction usually shows normal expiratory flow but diminished inspiratory flow, when the FEF 50% / FIF 50% is greater than 1.0. In variable intrathoracic obstruction, PEF is reduced and expiratory flow remains constant until the site of flow limitation reaches the smaller airways. The inspiratory portion of the loop may be completely normal. The FEF 50% / FIF 50% will be much less than 1.0 depending on the severity of obstruction (Agarwal & Gupta, 2007).

3. Peak expiratory flow (PEF) is the highest air flow achieved during the highest forced expiration initiated at the end of the inspiration. PEF is an extremely effort-dependent parameter, and low or inconsistent values may be due to insufficient subject effort. In other words, PEF values can indicate the quality and/or reproducibility of subject effort. All Flow Rates are measured in L/sec (ATS: Standardization of spirometry update, 1995).

Abnormalities detected in spirometery flow-volume curves

Obstructive disorder is increased airway resistance combined with decreased lung ventilation resulting in reduced peak expiratory flow (PEF) and decline in airflow to complete exhalation follows a distinctive dropping (or concave) curve. Obstruction can be classified as obstruction of the upper respiratory tract extrathoracic, central (bronchial), obstruction of the lower respiratory tract peripheral (small airways). Also, general obstruction of the respiratory tract -foreign bodies, tumours, lymph nodes, cysts, goitre, tracheal or bronchial collapse and bronchial reflexes (Thorn et al., 2012).

Restrictive disorder is restricted elasticity of lung or thorax combined with reduced lung volume. The pattern observed in the expiratory trace with restrictive defect is normal in shape but there is an absolute reduction in volume. Restriction can also be classified as lung diseases (pulmonary), diseases of the pleura (pleural) or diseases of thoracic wall (thoracal) (Vandevoorde et al., 2006).

Second, body plethysmography is the test that gives information about absolute volumes of air in the lung that spirometry cannot provide. Thus Plethysmography is a different approach

used to measure residual volume (RV), Functional Residual Capacity (FRC), and total lung capacity (TLC). Unlike gas dilution test, only plethysmograph measures all the gas in the patient's lungs, whether it communicates with the large airways or is trapped behind closed airways. For this reason, the volume measured by body plethysmograph is referred to as the intrathoracic gas volume (VTG) (Borg & Thompson, 2012).

Body plethysmography is used for making two kinds of pulmonary function measurements. The intrathoracic gas volume (VTG) which can be used to determine TLC and airway resistance (Raw), the difference in pressure between the mouth (atmospheric) and the alveoli, related to gas flow at the mouth (Criee et al., 2011).

Types of direct measurements made with a body plethysmograph;

There are three types of measurement that can be derived from a body plethysmograph. Inspiratory and expiratory airflow rates during the subject's breathing cycle, air volume changes inside the sealed cabinet that result from expansion and contraction of the subject's thorax and changes in air pressure at the subject's mouth. The cabinet air volume changes are used to reflect changes in lung volume while mouth pressure changes, when the subject's airway is mechanically obstructed and this is the change in alveolar pressure. Readings of mouth (alveolar) pressure compared against change in cabinet air volume are used to determine lung volume. While cabinet air volume changes compared against subject ventilator air flow rates are used to determine airway resistance (Criee et al., 2011).

Common body plethysmography measurements:

Intrathoracic gas volume (VTG) – is the gas contained in the thorax whether in communication with open airways or trapped in any section of the thorax. VTG is usually measured at the end of the expiratory level usually equal to FRC. It may also be measured at other lung volumes and then corrected to relate to FRC (Criee et al., 2011).

Tidal volume (TV) – The amount or volume of air that is inhaled or exhaled in each normal breath. Tidal volume indicates a subdivision of the lung; when tidal volume is precisely measured, as in gas exchange calculation, symbol VT is used.

Vital capacity (VC) - All the air contained in the lungs between total lung capacity and residual volume. The VC is a non-forced measurement. It is often measured at the start of the session to familiarize the patient with the equipment.

Inspiratory capacity (IC) - The whole amount of air that can be inhaled after quit exhalation. The inspiratory capacity represents approximately two thirds (2/3) of the Vital Capacity in subjects with normal lung function (Borg & Thompson, 2012).

Residual volume (RV) - The amount of inspired air remaining in the lungs after all the expired air that can be voluntarily removed from the lungs exhaled.

Functional residual capacity (FRC) - the volume of air remains in the lungs at the end of passive expiration particularly in lungs parenchyma tissues. The chest wall and the elastic recoil forces of the lungs during FRC phase are equal but opposite of each other. Also, there is no action by other respiratory muscles or the diaphragm (Vandevoorde et al., 2006).

Expiratory reserve volume (ERV) - The maximal volume of gas that can be exhaled from the end of a normal tidal volume. It represents approximately one third (1/3) of the Vital Capacity in subjects with normal lung function. Inspiratory reserve volume (IRV) - The maximal volume that can be inhaled from the end of inspiratory level. Total lung capacity (TLC) is volume of air within the lung at the end of a maximal inspiration. TLC is the sum of the static lung volumes (Xavier, Ceneviva, Terra, & Sankarankutty, 2010).

Airway resistance (Raw) - The majority of normal Raw (approximately 90%) is the result of air flow through airways greater than 2.0 mm in diameter. These include the larger, central airways. The airways themselves may be large in diameter, but their total cross sectional area at any given level in the tracheobronchial tree is limited. A large airway disorder can rapidly demonstrate itself through increased Raw and work of breathing (WOB). The smaller peripheral airways (less than 2.0 mm in diameter) normally contribute very little to Raw because their combined cross sectional area is so large. This is the reason why a significant amount of small airway disease must occur before the subject's Raw and WOB will be noticeably affected. The unit of measurement for Raw is cm H_2O/L/sec (Ruppel, 2012).

Airway conductance (Gaw) - is a measure of the flow that is generated from the available drive pressure. The unit of measure for Gaw is L/sec./cm H_2O.As values for Raw increase, the values for Gaw will decrease. Normal values of Raw in adults range from 0.6 to 2.4 cm H_2O/L/sec. Gaw in healthy adults is between 0.42 and 1.67 L/sec./cm H_2O (Flesch & Dine, 2012).

Third, diffusing lung capacity for carbon monoxide (DLCO) - lung diffusion testing looks at how well gases are passing from the air sacs of the lungs into the blood, to determine whether the lung is sending enough oxygen in the blood. The test measures the "diffusing (Spreading) capacity of the lung for carbon monoxide" or DLCO. It is one of the most sensitive indicators of dysfunction within the parenchyma and connective tissue. Results of this test can provide information about the amount of damage or abnormality that is present where the air and blood meet. DLCO is reported in millilitres of CO/minute/millimetre of mercury .The average DLCO value for resting adult patients by the single- breath method is 25 ml CO/min/mmHg. The expected DLCO value in a healthy patient varies directly with the patient's lung volume (Johnson, 2000).

Carbon monoxide binds with hemoglobin to form carboxyhemoglobin (COHb) approximately 210 times more rapidly than oxygen with hemoglobin to form oxyhemoglobin. The half life of COHb is eight hours, due to the high binding capacity of carbon monoxide to hemoglobin. For this reason, this gas is used to ascertain the condition of the alveolar capillary membrane. The test gas used consists of 0.3% carbon monoxide, either 10% helium or 0.3% methane, 21% oxygen, and nitrogen for the balance. Significance of DLCO is decreased in restrictive diseases (alveolar fibrosis), decreased by space occupying tumors and after Lung resection and decrease in lung tissue (emphysema).

Single-breath method (DLCO-SB) is the most complex and requires the most attention and skill for its successful completion as it is performed with a potentially difficult breathing manoeuvre, moderately affected by V/Q abnormalities, and change in lung volume at the time of measurement can significantly affect the test results (Hughes & Pride, 2012).

The test start with normal breathing followed by asking the patient to exhale down to the reserve volume (RV).Then the patient inhale rapidly to inspiratory vital capacity manoeuvre and holds the breath for 10 seconds and exhale rapidly back down to the RV level.

The factors influence the DLCO measurements are

- Physiological factor: haemoglobin (Hb) has a direct correlating with DLCO (1g/dl decrease Hb- 4% decreased DLCO, 1g/dl increase Hb – 2% increased DLCO). An increase in carboxyhemoglobin (COHb) level will influence DLCO result in two manners, reduces differential driving pressure across alveolocapillary membrane and decreases available binding sites on hemoglobin (1% increase in COHb decreases DLCO by 1%).
- Technical factor: pressure of inspired oxygen is inversely related to DLCO (decreased pressure of inspired oxygen per mmHg will increase DLCO by 0.31%). Also, supplemental oxygen should be discontinued for more than 5 minutes before the procedure.
- Gender and ethnicity- DLCO is lower in women for a given height and lower in Asians and African-Americans. Also, age, height and muscle mass are influencing the DLCO result.
- Smoking and alcohol consumption should be stopped one day before the DLCO test.

Also, increased DLCO are influenced by living at high altitude, left-to-right cardiovascular shunt, exercise, left heart failure, supine position, early polycythemia. Also, decreased DLCO are influenced by oxygen toxicity, radiation-induced fibrosis, sarcoidosis, scleroderma lung disease, pulmonary alveolar proteinosis and anemia (Dressel et al., 2008).

2.4.3. Significance and pathophysiology relating to PFT measurements:

Functional residual capacity (FRC) varies with body size, with change in body position, and with time of day. Normal FRC may also be affected by racial or ethnic background. Increased FRC is considered pathological. FRC values greater than approximately 120% of predicted values represent air trapping. Air trapping may result from emphysematous changes or from obstruction caused by asthma or bronchitis. Compensation for surgical removal of lung tissue or thoracic deformity can also cause elevated FRC. Increased FRC usually results in muscular and mechanical inefficiency of the respiratory system (Heinze & Eichler, 2009).

The chest wall and lungs themselves become "stiff" as lung volume increases. This causes an increase in the work of breathing. RV and FRC usually increase together. As RV becomes larger, increased ventilation is needed to adequately exchange oxygen and carbon dioxide (CO_2) in the lung. Patients with increased RV often display gas exchange abnormalities such as hypoxemia or CO_2 retention (Brewer, Orr, Filcher & Markewitz, 2011).

2.4.4. Other pulmonary function tests

Respiratory muscle strength test is creating the pressure differences driving ventilation. Respiratory muscle weakness is an essential clinical feature because in late stages, respiratory weakness leads to respiratory failure. Respiratory muscle dysfunction needs to be distinguished from lung function abnormalities, and should be measured separately. The two important techniques to test muscle strength are tests for Maximum Inspiratory Pressure

(MIP) and Maximum Expiratory Pressure (MEP) (Bosnak-Guclu, Gunduz, Nazliel & Irkec, 2012).

MIP is the lowest pressure developed during a forceful inspiration against an occluded airway. It is usually measured at maximal expiration (near residual volume).It is recorded as a negative number in either mmHg or cm H_2O. For the MIP test, the patient is instructed to exhale maximally to residual volume, then inspire maximally against the occluded airway and maintain the inspiration for 1 to 3 seconds. The first portion of each manoeuvre is ignored because it may include transient pressure changes that occur initially. The most negative value from at least three efforts is recorded (Singer, et al., 2011).

MEP is the highest pressure that can be developed during a forceful expiratory effort against an occluded airway. It is usually measured at maximal inspiration and reported as a positive number in either cm H_2O or mm Hg. For the MEP test, the patient inhales as much as possible, then exhales maximally against the occluded airway for 1 to 3 seconds. Longer efforts should be avoided as it may develop high thoracic pressure that reduces cardiac output (Eisner, et al., 2008).

Significance and pathophysiology for MIP and MEP:

Maximum inspiratory pressure (MIP) primarily measures inspiratory muscle strength. Healthy adults can generate inspiratory pressures greater than negative 60 cm H_2O. Decreased MIP is seen in patients with neuromuscular disease associated with respiratory muscle weakness or diseases involving the diaphragm, intercostals, or accessory muscles. MIP may also be decreased in patients with hyperinflation as in emphysema. The diaphragm

is flattened by the increased volume of trapped gas in the lungs. Patients with chest wall or spinal deformities may also have reduced inspiratory pressures. MIP is occasionally used to assess patient response to training of respiratory muscle strength. It is also frequently used in the assessment of respiratory muscle function in patients who need ventilator support.

Maximum expiratory pressure (MEP) primarily measures the pressure generated during maximal expiration. It depends on the role of the abdominal muscles and accessory muscles of respiration and the elastic recoil of the lungs and thorax. Healthy adults can generate MEP values more than 80-100 cm H_2O. Adult males may develop pressures greater than 200 cm H_2O. Decreased MEP is seen in neuromuscular disorders particularly those resulting in generalized muscle weakness and high cervical spine fracture (damage to nerves controlling abdominal and accessory muscles of expiration). Reduced MEP often accompanies increased RV as seen in emphysema. A low MEP is associated with inability to cough effectively as in chronic bronchitis, cystic fibrosis or other diseases that result in excessive mucus secretion. An effective cough is generally not possible when expiratory pressures are less than 40 cm H_2O ((Bosnak-Guclu, Gunduz, Nazliel & Irkec, 2012).

Accurate measurements of MIP/MEP depend largely on patient effort. The technician must instruct and encourage the patient how to do the manoeuvre. Low values may result if the patient fails to inhale or exhale completely before the airway is occluded. At least three maximal efforts recorded are acceptable. Elevated MIP/MEP results can be seen in patients with repeated efforts (training effect). Others may show decreasing pressures with repeated efforts (muscle fatigue). Best efforts should be within 10% or 10 cm H_2O, whichever is greater (Eisner, et al., 2008).

Maximum voluntary ventilation (MVV) - is the largest volume that a subject can breathe in and out of the lungs in one minute with maximum voluntary effort. This test is performed by having the patient breathe in and out as quickly and fully as possible for 12-15 seconds. The volume measured in that time period is then extrapolated to a value for one minute. This is demonstrated by the following equation for a 12-second breathing manoeuvre, the total volume of air moved during the test can be expressed as L/sec or L/min. Success in measuring MVV value depends greatly on subject effort. For this reason, the technologist plays a significant role in coaching the patient prior to and during the manoeuvre. Once a value for MVV has been determined, it is possible to judge whether or not subject effort was maximal. An estimated value for any patient or subject's attainable MVV, regardless of the presence of a disease, may be determined in the following way: **Measured FEV1×35= Estimated MVV**

It is likely that the patient effort was sub maximal if the measured value is considerably less than the estimated value. At least two acceptable manoeuvres should be determined to get MVV result. Otherwise test should be repeated until acceptable results are collected and test reproducibility is demonstrated (Cavalheri, et al., 2012).

MVV measurement reflects the status of thorax or lung compliance, airway resistance and the respiratory muscles compliance. This test value usually is requested by the surgeons, due to it is a fast and easy way to assess the strength of the patient's respiratory musculature prior to surgery. An abnormal result in MMV value advises that the patient has muscle weakness and may developed pulmonary problems after the surgery. Therefore MVV can be viewed as a

measure of respiratory muscle strength. Decreased values are seen in patients with moderate or severe obstructive disease.

Reduced results of MVV may also occur because of airway collapse and hyperinflation, as in emphysema. It is useful in interpreting a subject's ventilatory response to exercise during stress testing. Airway-obstructed patients who have an MVV less than 50L/min often have a ventilatory limitation to exercise. MVV may be normal in patients who have restrictive pulmonary disease. Disorders that limit lung or chest wall expansion may not interfere significantly with airflow. Patients with restrictive pulmonary disease can compensate by performing the MVV manoeuvre with low tidal volume and high breathing rates (Pitta et al., 2008).

2.4.5. Blood gases analysis tests

This is a diagnostic test used for clinical assessment of ventilation, acid-base status, oxygenation, electrolytes and metabolites. It is usually an invasive procedure in which a needle penetrates the protective barrier of the skin and directly enters the artery. There are complications associated with this procedure, therefore precaution and careful attention is needed in carrying out this type of procedure. The blood gas status plays a key role in the evaluation of the critically ill patient. Blood gas parameters can be divided into subgroups of acid-base status; oxygen status; blood oximetry; electrolytes and related metabolic parameters (Budak, Huysal & Polat, 2012).

2.5 The quality of evidence of previous studies:

The importance of post-CABG pulmonary complications, and their effects on the surgical outcome, appeared clearly in several publications in the past. For the above reason, several studies were conducted to investigate the benefit and the effectiveness of different types of lung expansion therapy to prevent or decrease PPCs. Jenking and colleagues (1989), investigated the benefits of DBE plus CPT and IS plus CPT after CABG as compared to control group, using self-breathing exercise only. The results showed no significant difference between the groups. However, FVC improved in treatment groups by 0.4 L, from day one after CABG (means = 1.9 L) to day five (means= 2.3L) measurements. Thomas and McIntosh (1994), conducted a meta-analysis to investigate the difference between IS, DBE and IPPB to treat or prevent PCCs as compared to a no therapy group. They searched all trials registered in MEDLINE and other health service systems from 1960 to 1992. The result showed no significant difference between the three groups of therapy. However, the incidence of PPCs increased significantly in no therapy group and that confirmed the importance of post-CABG lung expansion therapy to prevent or treat PPCs, particularly post-surgical atelectasis.

Matte et al., (2000), first evaluated post-surgical atelectasis after CABG by comparing IS therapy plus CPT, CPAP therapy plus CPT and two levels of BiPAP therapy plus CPT. The result showed that the rate of post-surgical atelectasis in IS group was 30%, as compared to 15% in CPAP and BiPAP groups. However, the cardiac output decreased significantly in BiPAP and CPAP groups. This is because the duration of both therapies was one hour, which

caused an increase in intrathoracic pressure. In addition, the study started all therapies after four hours from extubation from mechanical ventilator which may have delayed the early effectiveness of lung expansion therapy. The study methodology evaluated the measurements during the first two post-operative days only and that led to a shorter time evaluation.

Another study by Pasquina et al. 2004 compared the difference between BiPAP and CPAP therapies to treat or prevent post-surgical atelectasis after cardiac surgery. The duration of each therapy was 30 minutes four times daily. However, in the methodology of the study, the therapy was applied only after patients developed moderate atelectasis. The type of CPAP system used was a gas mixer flow system in which the CPAP pressure delivery depends on the flow rate. The result showed an improvement in atelectasis in BiPAP group as compared to CPAP group. However, gastric distension and the increase of intrathoracic pressure is the most important concern about BiPAP therapy after CABG.

Study by Muller, et al. (2006) compared the difference between CPAP therapy and intermittent pressure therapy after CABG during the first three days after extubation from mechanical ventilation. The result showed no significant difference between both groups in oxygenation. However, there was a significant difference in lung volume in the intermittent pressure group. The study methodology used pressure setting of 5 cmH_2O in CPAP group and 20-30 cmH_2O in intermittent pressure group. Both therapies were applied for 15 minutes and three times only (at 3, 24 and 48 hours) after CABG. The pressure setting applied in the intermittent pressure group was high and may have increased the intrathoacic pressure. Also, the time period for CPAP therapy was shorter than the current study and the frequency of

therapy was only three times a day, which may lead to decrease in the effectiveness of the therapy. Romanini, et al., (2007), compared IPPB therapy and IS therapy to treat or prevent post-surgical atelectasis. The result showed significant increase in SpO_2 after 48 hours in IPPB group ($p=0.007$) and a significant increase ($p=0.02$) in expansion of respiratory muscles toward IS group. However, IPPB therapy was applied for just ten minutes which may have lead to reduced effectiveness of the therapy.

As shown above, a few studies in the past evaluated the benefit of CPAP via mask therapy to prevent or treat post-surgical atelectasis after CABG. The present study evaluated the use of CPAP via mask therapy to treat or prevent post-surgical atelectasis after CABG by using different method and modality, time period and frequency of CPAP therapy. Also, the present study was the first study to evaluate the benefit of new technology of CPAP system with auto-leak feature.

2.6 The validity and reliability of present study outcomes

The present study used six outcome variables, including inspiratory capacity (IC), oxygen saturation (SpO_2), heart rate (HR), respiratory rate (RR), chest x-ray and sputum induction (SI), to evaluate the effectiveness of CPAP via mask therapy to treat or prevent post-surgical atelectasis after CABG. All variables have been used before in the previous studies and found to be valid and reliable measures to evaluate the effectiveness of three regimes (Ebeo, et al., 2002; Pasquina, et al., 2004; Muller, et al., 2006; Romanini, et al., 2007; Renault, et al., 2009; Guimaraes, et al., 2009). Lung expansion capacity can be affected by a decrease or increase in IC, so it can be used as an indicator for improvement or deterioration of post-surgical atelectasis. Also, the risk of post-operative pulmonary complication can be identified

by significant reduction in IC after major thoracic surgery (Thomas & Mcintosh, 1994, Doyle 1999).

Arterial oxygen saturation (SpO_2) has been measured by a pulse oximeter for the last two decades, as this type of non-invasive technology is easy to use and has accepted accuracy (Valdez-Lowe, Ghareeb & Artinian, 2009). Cardiopulmonary bypass (CPB) during cardiac surgery is usually associated with post-operative hypoxemia due to decrease in oxygen in the blood vessels. Several factors can be the reason for post-operative hypoxemia. However, atelactasis seems to be the primary factor causing hypoxemia after CABG due to the increase in intrapulmonary shunt associated with post-operative atelecatasis (Weissman, 2004). An animal CABG study for post-operative lung expansion therapy by Magnusson, Zemgulis, Wicky, Tyden and Hedenstierna (1998) showed improvement in post-operative hypoxemia due to the decrease of atelectasis as a result of the therapy. Also, several studies in post CABG patients (Murphy, Szokol, Curran, Votapka & Vender, 2001; Claxton, Morgan, McKeague, Mulpur & Berridge, 2003; Tschemko, et al., 2002) showed improvement in arterial oxygenation related to a decrease in intrapulmonary shunt due to the reduction of post-operative atelectasis by lung expansion therapy (such as IS and CPAP). For the above reasons the present study used SpO_2 to compare the improvement in post-operative atelectasis between the groups of therapies, as the improvement in atelectasis after CABG results in improvement in post-operative hypoxemia.

The measurement of RR is a very important sign to measure the patient's work of breathing and it can be used to determine post-surgical atelectasis improvement or deterioration (Weindler & Kiefer, 2001). The use of RR to determine the improvement of post-surgical atelectasis has been used in several studies in the past such as (Muller, et al., 2006 & Romanini, et al., 2007). The increase in heart rate provides a good sign of decreased oxygenation in the blood (hypoxemia) which may lead to increased lung collapse (atelectasis) after surgery (Weissman, 2004).

A chest X-ray is the making of film records (radiograph) of internal structures of the chest by X-rays. It can help determine the improvement or deterioration of lung collapse after surgery. Gosselink, et al., (2000) and Saxena, et al., (2007) used the chest X-ray to evaluate the improvement of post-surgical atelectasis. Sputum Induction (SI) is a procedure to obtain deeply coughed-out sputum. A specimen is then sent to the laboratory for sputum culture. IS is used to determine the presence of any chest infection which may worsen post-surgical atelectasis. Quick diagnosis of chest infection and its immediate treatment usually leads to better surgical outcomes. Several studies in the past used SI to determine chest infection and its effect on post-surgical atelectasis (Gosselink, et al., 2000 & Pasquine, et al., 2003).

The present study used the above six variables because, they are simple and direct measurements, valid and reliable measurements, usually used for post-CABG in the hospital where this study was conducted, do not require a lot of patient effort, do not require extra cost, and the cardiac surgeons agreed to obtain these measurements in their patients.

2.7 Literature review summary:

Post-operative pulmonary complications are common after cardiac surgery particularly post-surgical atelectasis. Due to its frequent occurrence, it may increase the post-operative risk factors for morbidity and the length of hospital stay. The incidence of post pulmonary complications (PPCs) range from 6 to 70 percent in major thoracic or abdominal surgery depending on the type of surgery and patient risk factors. The reductions of pulmonary function variables particularly FVC, VC and IC are common after cardiac surgery, which range from 30% to 70% of pre-operative values. These reductions take at least three weeks to recover towards normal pulmonary function values after the surgery (Jenkins, et al., 1989; Pasquina, et al., 2004; Renault, et al., 2009).

Post-operative morbidity and mortality usually occur as a result of pulmonary complications associated with major thorax or upper abdominal surgical procedures. Understanding post-operative pulmonary morbidity risk factors will decrease or prevent the occurrence of these problems. The mean potential predictors for PPCs are the type of surgical procedure, smoking, age and patient's diet.

There is a requirement to reduce or prevent these potentially serious incidents to improve the surgical outcomes. Lung expansion methods are one of most important ways to solve these pulmonary complications and have had widespread use in the last two decades. However, the best respiratory care methods to reduce or prevent PPCs have not been specified in the previous studies and trials (Pasquine, et al., 2003; Freitas, et al., 2007). There was little, or

no evidence to support the use of IPPB therapy or blow bottles to reduce the occurrence of PPCs. IS therapy may decrease the incidence of PPCs in low risk abdominal surgery but not in major surgery.

Pre-operative respiratory care is a very important way to prevent PPCs particularly when combined with post-operative methods of therapy. Several studies agreed to the benefit of pre-operative respiratory care management (Myrianthefs and Batistaki, 2007), there was 17% decrease in PPCs (Yanez-Brage, et al., 2009) and 16% decrease in PPCs (Hulzebos, et al., 2006). Pre-operative respiratory therapy care regimens seem to have had indirect effect in reducing the incidence of PPCs.

Several studies and trials investigated the effectiveness of respiratory physiotherapy from different aspects such as single therapy (Jenkins et al., 1989; Thomas and McIntosh, 1994; Muller, et al., 2006; Renault, et al., 2009), combined therapy (Forti, et al., 2009; Haesfener, et al., 2008; Borghi-Silva, et al., 2005; Denehy, et al., 2001; Hall, et al., 1996; Larsen, et al., 1994), to prevent PPCs (Hall, et al., 1991; Chumillas, et al., 1998; Pasquine, et al., 2003; Lawrence, Cornell & Smetana, 2006; Freitas, et al., 2007) or pre-operative care to prevent post-operative complications(Yanez-Brage, et al., 2009; Myrianthefs & Batistaki, 2007; Hulzebos, et al., 2006; Baudouin, 2003; Arthur, et al., 2000). The results showed that the use of CPAP therapy reduces the incidence of PPCs and seems to be accepted as physiologically rational but is not a compulsory pre-requisite.

According to Saxena, et al., (2007), Overend, et al., (2001) and Gosselink, et al., (2000), Incentive Spirometry (IS) is a commonly used method of therapy for post-operative patients.

However, the effectiveness of IS therapy has been questioned by several publications such as (Renault, et al., 2009; Guimaraes, et al., 2009; Romanini, et al., 2007; Brasher, McClelland, Denehy & Story, 2003; Matte, et al., 2000; Stiller, et al., 1994; Jenkins, et al., 1989) and other publications debate the use of IS therapy for major post-operative patients such as (Freitas, et al., 2007; Pasquina, et al., 2003; Brooks, et al., 2001; Overend, et al., 2001).

All methods of therapy such as IS, coughing and breathing exercises or CPAP have a valuable role to play in the prevention or the treatment of post-operative pulmonary complications. However, the type of therapy which should be used is not completely clear yet. For the reasons above, an alternative method of therapy should be investigated through a prospective trial to clarify the difference in effectiveness between IS therapy and other therapy such as CPAP therapy to treat post-operative pulmonary complications in CABG patients. The present study evaluated the effectiveness of early use of CPAP therapy against IS therapy, as the latter is most frequently used to treat or prevent post-surgical atelectasis after cardiac surgery, particularly CABG procedure.

This research aims to compare CPAP therapy and the regular IS therapy to treat or prevent acute atelectasis in post-operative cardiac patients. It aims to assess the effect of early use of CPAP therapy to improve lung function, reduce hospital stay, reduce morbidity and mortality, and ensure early recovery from critical care units. In addition, it aims to assess the experience of medical staff involved in the studies and the participants about the new way of treatment.

Chapter 3

General research methodology for the two quantitative studies

3.1 General research methodology:

This research comprised of two quantitative studies, as follows:

The first study compared three groups: (i) ***the control group (IS group)*** used the regular treatment incentive spirometry (IS) (IS 15 times per hour for three days); (ii) ***the first trial group (CPAP 2-hr)*** used continuous positive airway pressure (CPAP) therapy via mask for half an hour, every two hours for, three days; and (iii) ***the second trial group (CPAP 4-hr)*** used the CPAP therapy via mask for half an hour every four hours for three days. This is reported in chapter five.

The second study compared two groups, ***the third trial group (IS plus CPT)*** (IS 15 times per hour with CPT for three days) with ***the fourth trial group (CPAP 2-hr plus CPT)*** (CPAP via the mask for half an hour every two hours with CPT for three days). This is reported in chapter six.

Inclusion criteria:

Patients who were:

- Male and female, aged 50 or over,
- Smokers,

- Post cardiac surgery,
- Extubated from mechanical ventilation,
- Able to understand and answer questionnaires.

Exclusion criteria:

Patients who had:

- Massive atelectasis (more than 50% of alveoli collapsed),
- Predicted mortality rate >30% (depending on pre-surgery patient assessment),
- Undergone repeat cardiac surgery,
- Severe pulmonary oedema,
- Severe bleeding (more than 100ml per hour),
- History of chronic lung diseases,
- Unstable angina,
- Contraindication for CPAP or IS therapy.

Outcome Variables:

In this study, testing and measurement were the most important elements due to the effect of different treatment methods in treating or preventing atelectasis on post-operative cardiac patients. These tests included inspiratory capacity (IC), oxygen saturation (SpO_2), heart rate (HR), respiratory rate (RR), chest x-ray and sputum induction (SI). **A pre-test** was measured before the cardiac operation, **baseline- tests were** measured after the endotreacheal tube was removed (extubation) for each patient, **daily-tests** were measured after 12 hours, 24 hours

and 48 hours, and **post-test** was measured at the end of the third day or after the lung was opened fully and treatment was discontinued.

Measurement variables:

Inspiratory Capacity (IC) (Litres/Minute):

Inspiratory Capacity is the maximum volume of gas inspired after a quiet expiration (Weindler & Kiefer, 2001). Lung expansion capacity can be affected by a decrease or increase in IC, so it can be used as an indicator for improvement or deterioration of post-surgical atelectasis. Also, the risk of post-operative pulmonary complication can be identified by significant reduction in IC after major thoracic surgery (Thomas & Mcintosh, 1994; Doyle 1999). Pulmonary function variables such as force vital capacity (FVC), vital capacity (VC), inspiratory capacity (IC), force residual capacity (FRC) and force volume expiratory in one second (FEV_1) are the variables most affected by cardiac surgery procedures, particularly CABG (Vargas, et al., 1997).

The lung volume is affected as a result of shallow breathing or lung airway blocked by mucus associated with post-surgical lung collapse (atelectasis). The main reasons for these respiratory changes are pain, surgical and anaesthetic alterations, and pulmonary dysfunction (Westwood, et al., 2007; Jensen & Yang, 2007). The author of the present study chose IC measurement for comparison between the groups as it is a simple, direct measurement of lung volume, it is accurate and because it is not costly (Pinheiro, et al., 2011). Also, the improvement in lung volume leads to improvement in atelectasis. The incentive spirometer manufacture advises its use for IC measurement and guarantees the accuracy.

The use of incentive spirometer as a measurement tool for IC and comparison between the groups has been used by a previous study (Bellet, et al., 1995). Bastin and colleagues in (1997) conducted a study to evaluate the reliability of incentive spirometer measurement after major surgery. The result showed excellent correlation between the measurement of portable pulmonary function machine and incentive spirometer for VC and IC variables in the patient's bedside measurements. The two important lung volume equation formulas are IC equal tidal volume (TV) plus inspiratory reserve volume (IRV) and VC equals IC plus expiratory reserve volume (ERV). The measurement of IC in the present study was by an incentive spirometer and its correlated well as regards reliability and accuracy. The measurement was carried out by a well-trained respiratory therapist

Respiratory Rate (RR) (Breaths/Minute, bpm):

Respiration is composed of inspiration which has two parts - expansion of the thorax and descent of the diaphragm followed by expiration, which is passive (Lim et al., 2002). The measurement of RR is very important sign to measure the patient's work of breathing and it can be used to determine post-surgical atelectasis improvement or deterioration (Weindler & Kiefer, 2001). In the present study, RR measurement was carried out by a well-trained respiratory therapist.

Heart Rate (HR) (Beats per Minute, BPM):

Heart Rate is the frequency of ventricular (heart chambers) contractions in one minute. It is the total rate measured per minute (Pedersen, Moller & Hovhannisyan, 2009). The increase in heart rate provides a good sign of decreased oxygenation in the blood (hypoxemia) which

may lead to increase lung collapse (atelectasis) after surgery (Weissman, 2004). In the present study HR was measured by a Pulse Oximeter under the supervision of a well-trained respiratory therapist. The Pulse Oximeter was calibrated in accordance with manufacturer's advice to ensure accuracy and reliability.

Saturation of Peripheral Oxygen (SpO_2 in Percentage %):

Arterial oxygen saturation has been measured by a pulse oximeter for the last two decades, as this type of non-invasive technology is easy to use and has accepted accuracy (Valdez-Lowe, Ghareeb & Artinian, 2009). Pulse oximeter is usually used in several places in the hospital, such as recovery room, critical care units and hospital wards. There are several factors that decrease the accuracy of this type of monitor, such as abnormal carboxyhemoglobin, methemoglobin or presence of nail polish when finger site is used (Wilson, Cowan, Lord, Zuege & Zygun, 2010; Lee, Mayberry, Crapo & Jensen, 2000). However, the present study avoided all these factors to make sure the result of the pulse oximeter was accurate.

Saturation of arterial oxygen is a ratio expressed as a percentage of the volume of oxygen carried, to the maximum volume that can be carried by the haemoglobin. SpO_2 was measured by a pulse oximeter device, which provided estimates of arterial oxyhemoglobin saturation by utilizing selected wavelengths of light to noninvasively determine the saturation of oxyhemoglobin (Jensen, Onyskiw & Prasad, 1999). In the present study SpO_2 measurement was taken by a well-trained respiratory therapist and the pulse oximeter was calibrated daily to ensure validity and reliability.

Since the discovery of oxygen saturation measurement by simple pulse oximetry (light absorption properties of haemoglobin) in 1930, several developments have been made in the pulse oximeter technologies. The latest development using pulsatile signal technology was introduced by Takuo Aoyagi in 1971 (Wukitsch, et al., 1988). After this improvement, pulse oximetry was moved from research to clinical use in 1980 (Kelleher, 1989).

A probe (clip-on or adhesive), placed in the finger or ear is usually use in pulse oximetry to measure oxygenated haemoglobin by absorption of specific wavelengths of the light. The probe contains two lights which transmit wave length of the light through the blood to a photodetector on the other side of the probe (Jensen, Onyskiw & Prasad, 1999). The amplitude of light transmitted is influenced by the wave length of light used, the oxygen saturation of haemoglobin and the size of the arterial pulse change (Sakamoto, Furuya & Kanai, 2007). The finger probe is more accurate than other types of probe (Batchelder & Raley, 2007). The present study used the latest pulse oximetry technology and finger probe with all participants to confirm SpO_2 measurements accuracy.

The difference in accuracy between actual arterial oxygen saturation measured by blood gas analyzer (Vitro methods) and pulse oximetry measurement was + or -2%. Also, the range of 70% to 100% pulse oximetry measurements are the most accurate oxygen saturation measurement (Nijland, Jongsma, Nijhuis, Oeseburg & Zijlstra, 1995; Barker & Badal, 2008). The present study applied the previous two considerations for SpO_2 measurement to ensure accurate result.

Several studies in post CABG patients (Murphy, Szokol, Curran, Votapka & Vender, 2001; Claxton, Morgan, McKeague, Mulpur & Berridge, 2003; Tschemko, et al., 2002) showed improvement in arterial oxygenation related to a decrease in intrapulmonary shunt due to the reduction of post-operative atelectasis by lung expansion therapy (such as IS and CPAP). For the above reasons the present study used SpO_2 as a measurement to compare the improvements in post-operative atelectasis between the groups of therapies as the improvement in atelectasis after CABG results in improvement in post-operative hypoxemia.

Sputum Induction (SI):

Sputum Induction is a procedure to obtain deeply coughed-out sputum. A specimen is then sent to the laboratory for sputum culture. Sputum for culture and sensitivity is placed on a Chocolate Agar Plate, Blood Agar Plate or Machonky Agar and incubated at 37 degrees centigrade for 24 hours (Ganguly, et al., 2008). Quality Control is maintained every day to ensure the accuracy and reliability of the results. Also, SI sample, in the present study was taken by a well trained respiratory therapist, for all participants, to confirm accuracy and reliability.

Chest X-ray:

A chest X-ray is the making of film records (radiograph) of internal structures of the chest by passage of X-rays or Gamma Rays through the body to act on a specially sensitized film (Ashizawa, Hayashi, Aso & Minami, 2001). It is obtained by using an X-ray machine such as a Vertex or Moltex Cassette. Monthly calibrations are carried out by radiology technicians to maintain the accuracy and reliability of the results. A chest X-ray is taken by a well-trained

radiology technician. The consultant of radiology (radiologist) blindly interpreted all X-ray result in the present study.

Chest X-ray process in the hospital where this research was conducted; the primary nurse allocated to an elective cardiac surgery and cardiology patient requested a chest X-ray on the first day of his/her admission. All post-operative cardiac patients must had chest X-ray within 2 hours after stabilization. Chest X-ray was done on all post-operative cardiac patients on the morning of 1, 2, and 3 post-operative days. Also, Chest X-ray was requested one hour post chest tube removal. Chest X-ray was requested on all cardiac patients who underwent invasive insertion, for example CVP.

In addition, Chest X-ray was requested after one hour on all cardiac patients who underwent pleural tapping in a sitting position. (Siemen's Mobilette Portable x-ray). Chest X-ray was done in radiology department for all ambulatory patients. It was the responsibility of the primary nurse allocated to the patient to coordinate with the charge nurse to inform the attending physician of any changes in the cardiac patient's medical condition, so that a chest x-ray could be requested for SOB, desaturation and other such indications.

3.2 Patient mobilization process (management and method):

This type of patient mobilization or ambulation was applied to all post CABG patients who participated in all groups of therapies. Training procedure for mobilization and ambulation after CABG for all participants is explained below (Morris, Benetti, Marro & Rosenthal, 2010; Criner, Barnette & D'Alonzo, 2010). :

1. Before mobilization of the patient the therapist must confirm with the attending CCU nurse that the patient's condition is stable enough for the proposed procedure.
2. Request the assistance of the primary nurse to secure all lines during ambulation.
3. Inform the patient that he/she should ambulate as soon as possible after the operation to enhance the recovery process.
4. Instruct the patient that he/she should avoid pressure movement on the operated sternum.
5. Put pad or small pillow on the chest of the patient and instruct him/her to hold it in this position to stabilize or prevent movement in the sternum.
6. When the patient is in sitting position instruct him/her to keep holding the pad or small pillow on the chest while pushing both his legs on the ground to stand. Assist the patient in doing this movement if needed.
7. Assist the patient properly during the ambulation process to prevent injuries or falls.
8. Instruct the patient to stand upright with his chin elevated while standing and ambulating.
9. Instruct patient to breath normally throughout the ambulation process.
10. Ambulate the patient to the point of tolerance.

11. Document gait training and patient's response in progress.

The process of application of Passive Range of Motion (PROM) for Intubated and Sedated Patient is explained below:

1. The force for movement is external, being provided by the therapist or mechanical device. When appropriate, patient may provide the force and be taught to move the part with a normal extremity.
2. No assistance or active resistance is given by the patient's muscles crossing joints.
3. The motion is carried out within the free ROM, that is the range that is available without forced motion or pain.

The process of application of Active Range of Motion (AROM) for all participants is explained below;

1. Demonstrate to the patient the motion desired using PROM, and then ask the patient to perform the motion. Keep hands in position to assist or guide the patient if needed.
2. Assistance is given only as needed for smooth motion. When there is weakness, assistance may be required only at the beginning or end of ROM, or when the effect of gravity has the greatest moment arm (torque).
3. The motion is performed within the available ROM.

The Passive Range of Motion (PROM) and Active Range of Motion (AROM) Techniques include three main components.

First component is examination, assessment, treatment planning, evaluation and follow up action as explained below;

A. Examination:

- Examine the patient's impairments.
- Assess any treatment precautions.

B. Assessment:

- Assess degree of patient's impairment
- Assess level of function.
- Determine the degree of motion that can be safely applied. Consider the patient general health condition.

C. Treatment Planning:

Decide what patterns will best meet the goals. ROM techniques may be performed in the;

- Anatomical planes of motion: frontal, sagital, transverse.
- Functional patterns: motions used in activities of daily living (ADL).

D. Evaluation:

- Monitor the patient's general condition and responses during and after the examination and intervention. Note any change in vital signs, change in the temperature and colour of limbs, change in the ROM, as well as pain experience.
- Document and communicate findings and intervention in progress notes.

E. Follow Up Action:

- Re-evaluate and modify the intervention as necessary.

Second component is preparing the patient for mobilization method;

- Explain the procedure to the patient. Describe the plan and method of intervention.
- Free the region from restrictive clothing, linen, splints, and dressing. Drape the patient as necessary. Provide privacy and comfort.
- Position the patient in comfortable position. Apply proper body alignment and stabilization that will allow movement through the available ROM.
- Position yourself so that proper body mechanics can be used.

Third component is application of techniques:

- To control movement, grasp the extremity around the joints. If the joints are painful, modify the grip, still providing the support necessary for control.
- Support areas of poor structural integrity such as hypermobile joints, recent fracture site or paralyzed limb segment.
- Move the segment through its complete pain-free range to point of tissue resistance. Do not force beyond the available range. If you force motion, it becomes stretching technique.
- Perform the motions smoothly and rhythmically, 5 to 10 repetitions. The number of repetitions depends on the objectives of the program and the patient's condition and response to the treatment.

3.3 Pain assessment and management of post CABG patients:

A patient, who is wheeled from theatre, is still intubated with continuous protocol infusion and the dosage requirements are usually in the range of 4 – 12 mg/kgBW/hour. In patients with poor general condition and in hypovolaemic state, the dosage may be reduced depending on the severity of the patient's condition. Once the anaesthetics are weaned off, patient may be able to respond sufficiently whether they have pain or not. Some pain following surgery related causes may be either from sternal incision and/ or rib spreading. The chest drains or the leg wound, if they have Saphenous vein graft may experience increased pain and discomfort due to the need for further incisions into the parietal pleura and greater stretching of the intercostal muscles. Indicators of pain are increased blood pressure, tachycardia, sweating and shivering. Morphine Sulphate is the analgesia of choice in the immediate post-operative patient and can be given as a 1 mg/ml intravenous infusion (Hansdottir, et al., 2006).

The effect of suppression of respiratory drive may need mechanical ventilation until patients are stable and ready to be weaned. Following extubation, oral analgesia is preferred as there is less risk of respiratory depression. Paracetamol is the first choice to be given as regular dose 0.5 – 1 g every 4-6 hours to a maximum of 4 g daily. Alternatively, a low dose of Non Steroidal Anti-Inflammatory Drugs (NSAID's), example Ibuprofen up to 1.2 gram daily may be given. NSAID's are also a special hazard in patients with cardiac disease, liver insult and renal impairment. Tramadol Hydrochloride is indicated for moderate to severe pain, to be given orally 50 – 100 mg every 4 hours. A total of more than 400 mg daily is not usually required. For post-operative pain, 100 mg is given initially, then 50 mg every 10-20 minutes,

if necessary, during the first hour to a total of a maximum of 250 mg (including initial dose) in the first hour. Tramadol cannot be given with impaired consciousness and excessive bronchial secretions.

Side effects are diarrhea, fatigue, gastritis, flatulence, rarely anorexia, syncope, hypertension, bronchospasm, dyspnoea, wheezing, seizure, paraesthesia, muscle weakness and blood disorders. However, Morphine 3 – 5 mg intravenously is still required prior to chest drain removal. In chronic intractable pain, it is given by transdermal route (Transdermal Fentanyl) = 25 mcg/ hr and patch is replaced every 72 hours and replacement patch is sited on a different area. (Avoid using the same area for several days; apply to dry, non- irritated, non-hairy skin on torso or upper arm.

3.4 Pilot study:

A pilot study was conducted to estimate the sample size ahead of the first quantitative study in this research project. The participants were recruited from the patients scheduled for cardiac surgery in King Fahd Armed Forces Hospital in Jeddah, Saudi Arabia. The participants who fitted the inclusion criteria (smoker, haemodynamically stable, healthy lungs and above 50 years old) participated in this pilot study. Patients who had massive atelectasis (more than 50% of alveolar collapse), predicted risk of mortality more than 30% (depending on pre-surgery patient assessment), those who had undergone repeat cardiac surgery, severe pulmonary edema, severe bleeding (more than 100ml per hour), history of chronic lung diseases, unstable angina, and contraindication for CPAP or IS therapy were excluded. The inclusion and exlusion criteria were chosen based on several reasons as explained below.

Firstly, smokers were included, because more than 90% of CABG procedures done in the hospital where this research was conducted, was on patients who were smokers. This subgroup of patients usually had difficulty to cooperate with regular lung expansion therapy used in the hospital. Secondly, haemodynamically stable patients were included because unstable patients may have other pulmonary complications which may lead to other types of atelectasis, other than post-surgical atelectasis. Thirdly, patients who had healthy lungs were included because patients who had a history of pulmonary disease usually had narrowing of lungs airways, or had thick mucus, which could result in collapsed alveoli, unrelated to the surgical procedure. Finally, elderly smoker patients (above 50 years old) after CABG usually became less cooperative than other subgroup of patients. The usual lung expansion therapy required cooperation of patients.

All potential participants who fitted the inclusion criteria (over a 12 weeks period) were called via phone by the researcher to come to the hospital to read the participant sheet and sign the consent form. The researcher explained in full detail to all participants the advantage and the disadvantage of each therapy (IS & CPAP therapies). Also, the researcher explained to them about the use of each therapy and that they would be randomly allocated to one of the three therapies.

Thirty three patients participated in this pilot study. The participants were divided randomly into three groups, 11 participants in each group (28 males and 5 female, mean age 59 ± 6.3 years). The control group used IS (Respiflo 5000 incentive spirometer manufactured by Tyco Healthcare Group LP in Mansfield, Massachusetts, USA) 15 times per hour, the first trial

group used CPAP via mask (4-6 cmH_2O) (the type of CPAP delivery system used in this study was ResMed VPAP III manufactured in Milton, Australia) for half an hour every two hours, while the second trial group used CPAP via mask (4-6 cmH_2O) for half an hour every four hours. Each group used the therapy for three days after extubation during the waking hours in the cardiac unit (usually from 6 a.m to 8 p.m).

The randomisation method used in this study is explained below:

The researcher gave the CCU head nurse a copy of the list of enrolled participants and three types of color cards (blue, green & yellow), equal to the total number of participants (for example, if the total number of participants were 30, the number of color cards was 10 blue, 10 green and 10 yellow). The head nurse included blindly one type of the color card to the patient's file before the patient went to the cardiac surgery operation room. The research team knew the definition of each color card, so when they saw the blue card it meant that the patient would participate in control (IS) group, green card for CPAP2hr group or yellow card for CPAP4hr group.

The researcher used the setting of CPAP therapy as 4-6 cmH_2O because the normal physiological PEEP equals 5 cmH2O. From the researcher's experience (of 15 years) this setting usually does not lead to an increase in intrathoracic pressure, which can cause a decrease in cardiac output. Several studies (Pasquina et al., 2004 & Muller, et al., 2006) in the past have used this setting to apply CPAP via mask therapy.

Inspiratory capacity (IC) (maximum volume of air inhaled after a normal expiration) measured in liters was used to compare the three therapy regimes. IC was measured by an incentive spirometer (Respiflo 5000 incentive spirometer manufactured by Tyco Healthcare Group LP in Mansfield, Massachusetts, USA) and was used to confirm the accuracy and reliability of IC measurements. The participants were asked to repeat the test three times and the largest volume was taken. It was measured after the cardiac operation as a baseline-test, and after three days as post therapy test.

IC variables was used in this study as the primary indicator for the improvement of post-surgical atelectasis, because there is a strong association between improvement in the lung volume and improvement of lung collapse (atelectasis). This study used the difference between baseline and post therapy measurements as the primary indicator to measure the effectiveness of each therapy.

At the same time, respiratory rate (RR), heart rate (HR) and saturation of peripheral oxygen (SpO_2 %) (saturation of arterial oxygen is a ratio expressed as a percentage of the volume of oxygen carried, to the maximum volume that can be carried, by the haemoglobin and measured by a pulse oximeter device) was measured for all groups. Also, chest x-ray was performed to confirm the improvement or the deterioration of post-surgical atelectasis (categorized as zero= normal, 1= mild, 2= moderate or 3= severe atelectasis). Sputum induction (a procedure to obtain deeply coughed-out sputum) was taken to diagnose chest infection or pneumonia (categorized as zero= no growth, 1= mild, 2=moderate or 3= heavy growth).

Failure was defined as a need for advanced therapy such as mechanical ventilation and Bi-level Positive Airway Pressure (BiPAP) or added CPT therapy. Secondary end points consisted of length of stay in hospital and 30 day mortality. The G power 3.1 statistical power analysis program was used to calculate the sample size for this study. It is a valid and reliable statistical power analysis program. Faul, Erdfelder, Lang and Buchner (2007) and Faul, Erdfelder, Buchner and Lang (2009) have used this program to estimate sample size, and have found it an accurate and a reliable program.

The result showed no significant difference between all groups of therapies. The G power 3.1 calculation result for estimating the sample size advised to enroll 32 participants in IS (control) group to made a significant difference in IC measurement between baseline and post therapy measures (baseline mean= 1.2 L, SD= 0.4 & post therapy mean= 1.5 L SD= 0.6). the G power calculation result for CPAP2hrs group advised to enroll 27 participants to made significant difference between baseline and post therapy measures in IC (baseline mean= 1.3 L SD= 0.4 & post therapy mean= 1.6 L SD= 0.5). Also, the calculation result for CPAP4hrs group advised to enroll 29 participants to be significant (IC baseline mean= 1.3 L, SD= 0.57& post therapy mean= 1.63 L, SD= 0.44). A copy of G power 3.1 calculation results are in appendix A.

The researcher chose the largest significant number of participants for determining choice of the sample size for the first study in this research project, and that is to enroll 32 participants in each group of therapy. The researcher decided to enroll 40 participants in each group of therapy, as it was predicted that some of the participants may change their decision, and

decide not to continue to participate in the study, or the participants may develop one of exclusion criteria during or after the surgery. In addition, some of the patients who may have been scheduled for the cardiac surgery, may live in another city and may not be able to travel to the hospital for medical reasons, or transportation problems, which leads to missing their cardiac surgery appointment.

Because sample size determined by the power calculation from the pilot study was confirmed as appropriate by first study, the values were carried forward to second study without the need for a second pilot study.

3.5 Pre-operative management of the research:

As a cardiac surgery requirement, the patient must be admitted to the hospital CCU ward three days before the surgery. When the potential study participants were admitted to the hospital, the charge nurse notified the researcher. After that, the researcher visited the patient to evaluate his or her medical status in case he or she developed one of the exclusion criteria. Then, the researcher explained to the participant the procedure of each therapy and how to use the equipment. In addition, the participants tried the devices for each therapy to get used to them. Then, the researcher asked relevant questions to the participants, to make sure that everything was clear to them. The participants were encouraged to ask questions about the therapy, and it was ensured that a proper explanation was provided to them.

The researcher always made sure that the participants fully understood each therapy procedure and their use before the surgery. Moreover, the research team explained to the participants how to do huffing and coughing exercise to expectorate the accumulated secretion in the lungs.

3.6 Health, Safety and Ethical Approval:

All procedures in this research followed the King Fahd Armed Forces Hospital patient safety guidelines. Also, this research was approved by the King Fahd Armed Forces Hospital Ethics Committee (see appendix B).

Chapter 4

First study

4.1 Title: Difference between continuous positive airway pressure via mask therapy and incentive spirometry to treat or prevent post- surgical atelectasis: prospective randomized study.

First study publications;

1. Article was published in the Saudi Medical Journal (please see abstract of this article in appendix C).
2. Abstract was presented as oral presentation in the Annual Conference of the European Respiratory Society held in Amsterdam from 24 to 28 of September 2011. Also, this abstract was published in European Respiratory Society Journal (Please, see a copy of the certificate in appendix D)

ABSTRACT

Objective

In regular medical practice for atelectasis treatment, Continuous Positive Airway Pressure (CPAP) via mask therapy is used if other therapies such as Incentive Spirometry (IS) and Chest Physiotherapy (CPT) have failed.

This study aims to assess the effect of early use of CPAP therapy to treat or prevent acute atelectasis in post-operative cardiac patients.

Methods

A pilot study suggested enrolling at least 32 participants in each group in order to be significant. One hundred eight patients from King Fahd Armed Forces Hospital (between March 2010 and March 2011) who met the inclusion criteria participated in this study. The participants were divided randomly into three groups, IS therapy, CPAP therapy every 2hrs or every 4hrs. Inspiratory Capacity (IC) was used to compare the three therapy regimes. Simultaneously, RR, HR and SpO_2 were measured for all groups. Failure was defined as requiring intubation, BiPAP or added CPT therapy.

Result

Thirty-six patients participated in each group (98 male and 10 female mean ages; 62 ± 9.3years). IC was increased significantly in CPAP2hrs group when compared to IS group or CPAP4hrs group. SpO_2 was decreased significantly in control group and CPAP4hrs when compared to CPAP2hrs group. Also, there were no significant differences in RR and HR between all groups.

Conclusion

Early use of CPAP via mask therapy for half hour every two hours had better outcomes to re-open collapsed alveoli after cardiac surgery than either CPAP every four hours or IS therapies.

4.2 Objective:

The goal of atelectasis treatment is to remove lung secretions and to re-expand the affected lung tissue. Post-surgical atelectasis can be treated by chest physiotherapy, focusing on deep breathing and encouraging coughing (Placidi, et al., 2006). Also, IS (the regular method to treat atelectasis) is often used as part of breathing exercises and is also used to prevent atelectasis after surgery (Agostini & Singh, 2009).

Once the IS therapy is used frequently on a regular basis, airway patency can be maintained and alveolar atelectasis prevented or reversed (Overend, et al., 2001). However, the effectiveness of IS therapy has been questioned by several publications (such as Renault, et al., 2009; Guimaraes, et al., 2009; Romanini, et al., 2007; Brasher, et al., 2003; Matte, 2000; Stiller, et al., 1994; Jenkins, et al., 1989) and other publications that debate the use of IS therapy for major post-operative patients such as (Pasquina, et al., 2003; Brooks, et al., 2001; Overend, et al., 2001).

CPAP therapy is a part of the main group of therapy called non-invasive ventilation (NIV) or non-invasive positive pressure ventilation (NPPV) (Kramer, et al., 1995; Thys, Roeseler, Reynaert, Liistro & Rodenstein, 2002). The clinical use of NPPV began with the introduction of intermittent positive pressure breathing (IPPB) in 1947, which was widely used to deliver aerosolized medications for 10 to 15 minutes several times a day (Pierson, 1997). When the CPAP via mask was introduced by Sullivan, *et al.*, (1981), it became the initial choice for the management of obstructive sleep apnea and was later used successfully with acute respiratory failure. During the last decade, the CPAP delivery system has been significantly developed both in the technology and patient interfaces (Mehta & Hill, 2001).

In past, several studies such as (Celli, Rodriguez & Snider, 1984; Larsen, et al., 1994; Rezaiguia & Jayr, 1996; Overend, et al., 2001; Pasquina, Tramer, Granier, & Walder, 2006; Freitas, et al., 2007; Renault, Costa-Val & Rossetti, 2008) used CPAP therapy to treat post-operative pulmonary complications and found no significant difference from other therapies. However, the type of CPAP delivery system used in these studies was not a stand alone system and was without any new features, such as auto-leak compensation, the period of CPAP therapy was less (10 to 15 minutes), and the frequency of the therapy was fewer (two to four times a day).

The above reasons influenced the effectiveness of CPAP therapy. All methods of therapy such as IS, coughing and breathing exercises or CPAP have a valuable role to play in the prevention or the treatment of post-operative pulmonary complications. However, the type of therapy which should be used is not completely clear yet.

This study aims to assess the effect of the early use of CPAP via mask therapy to treat or prevent acute atelectasis in post-operative cardiac patients. The study design is summarised in figure 7.

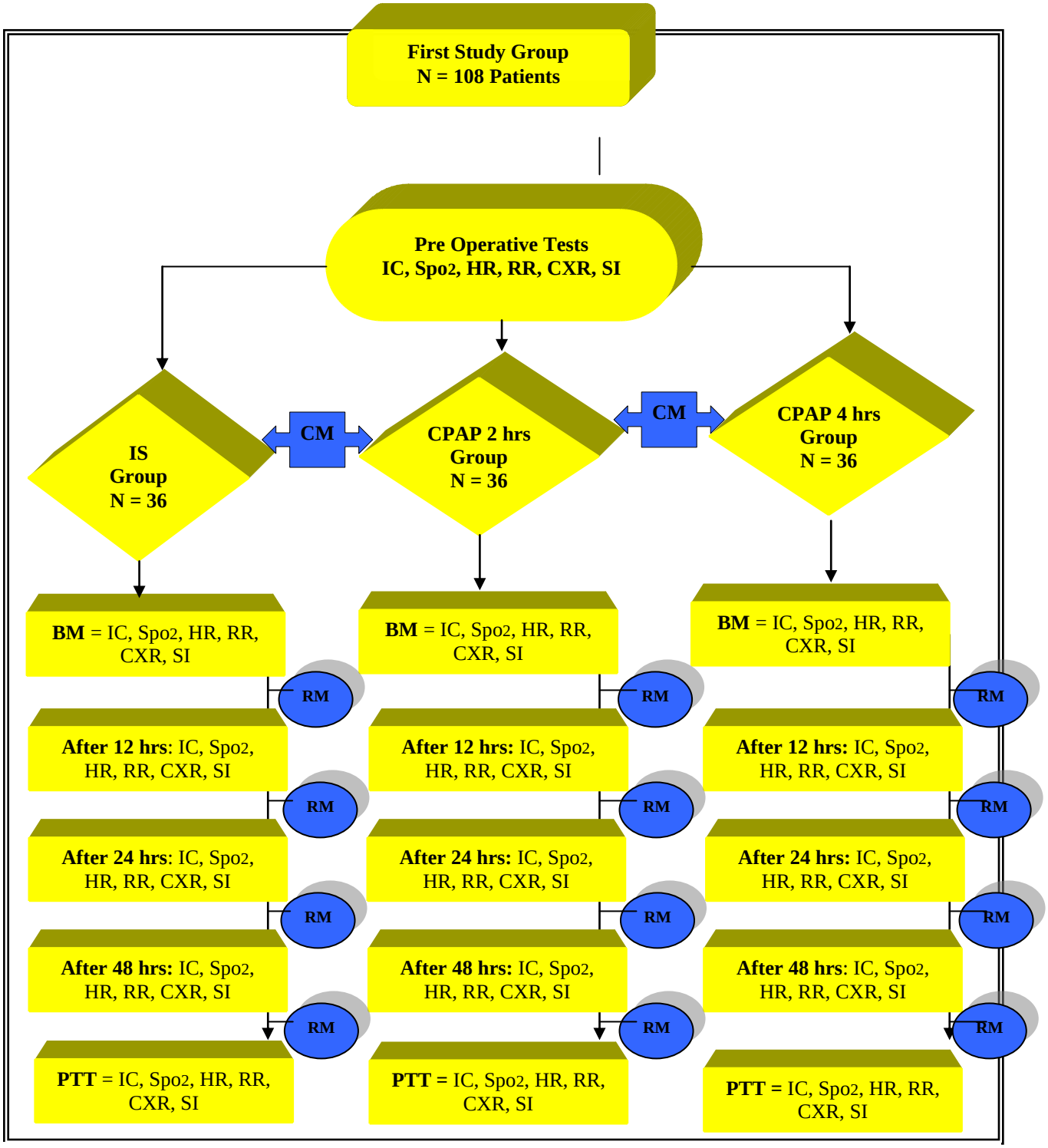
4.3 Methods:

This prospective randomized study recruited participants from the patients scheduled for cardiac surgery in King Fahd Armed Forces Hospital in Jeddah, Saudi Arabia from March 2010 to March 2011. Following the pilot study carried out to examine the significance of the sample size, it was suggested to enroll at least 32 participants in each group in order to be

significant. The patients who agreed to participate in the study came to the hospital to sign the consent form and read the participant's sheet before the cardiac surgery (see appendix E).

Some 120 participants agreed to enroll in the study; however five of them refused to participate after the cardiac surgery and seven were excluded as they developed one or more of the exclusion criteria after the surgery. One hundred and eight post cardiac surgery patients who met the inclusion criteria (smoker, haemodynamically stable, healthy lungs and above 50 years old) participated in this study. Patients who had massive atelectasis (more than 50% of alveolar collapse), predicted mortality rate more than 30% (depending on pre-surgery patient assessment), those who had undergone repeat cardiac surgery, severe pulmonary edema, severe bleeding (more than 100ml per hour), history of chronic lung diseases, unstable angina, and contraindication for CPAP or IS therapy were excluded.

The participants were divided randomly (using the method previously describe for the pilot study) into three groups; the control group used IS (Respiflo 5000 incentive spirometer manufactured by Tyco Healthcare Group LP in Mansfield, Massachusetts, USA) 15 times per hour, the first trial group used CPAP via mask (4-6 cmH2O) (the type of CPAP delivery system used in this study was ResMed VPAP III manufactured in Milton, Australia) for half an hour every two hours, while the second trial group used CPAP via mask (4-6 cmH2O) for half an hour every four hours . Each group used the therapy for three days after extubation during the waking hours in the cardiac unit (usually from 6 a.m to 8 p.m).



Abbreviations:
BM – Baseline Measurement
CM – Comparison Measurement
CPAP – Continuous Positive Airway Pressure
CXR – Chest X-Ray
RM – Repeated Measurement
HR – Heart Rate
SI – Sputum Induction
PTT – Post Treatment Test
RR – Respiratory Rate
Spo_2 - Oxygen Saturation in arterial blood content
IC – Inspiratory Capacity

Figure 7. First Study Design

Inspiratory capacity (IC) (maximum volume of air inhaled after a normal expiration) measured in litres was used to compare the three therapy regimes. IC was measured by an incentive spirometer (Respiflo 5000 incentive spirometer manufactured by Tyco Healthcare Group LP in Mansfield, Massachusetts, USA) and was used to confirm the accuracy and reliability of IC measurements. The participants were asked to repeat the test three times and the largest volume was taken. It was measured after the cardiac operation as a baseline-test, after 12 hours from the start of each therapy, after 24hours, 48 hours and post therapy.

At the same time, respiratory rate (RR), heart rate (HR) and saturation of peripheral oxygen (SpO_2 %) (saturation of arterial oxygen is a ratio expressed as a percentage of the volume of oxygen carried, to the maximum volume that can be carried, by the haemoglobin and measured by a pulse oximeter device) were measured for all groups. Also, chest x-ray was performed to confirm the improvement or the prevention of post-surgical atelectasis (categorized as zero= normal, 1= mild, 2= moderate or 3= severe atelectasis) and sputum induction (a procedure to obtain deeply coughed-out sputum) was taken to diagnose chest infection or pneumonia (categorized as zero= no growth, 1= mild, 2=moderate or 3= heavy growth).

Failure was defined as a need for advanced therapy such as mechanical ventilation and Bi-level Positive Airway Pressure (BiPAP) or added CPT therapy. Secondary end points consisted of length of stay in hospital and 30 days mortality.

The statistical package for social sciences (SPSS, Inc. Chicago, IL, USA) version 18.0 was used for the analyses of data and One-Way mixed model ANOVA and Tukey Post-Hoc tests

were used to examine the differences between the baseline and post therapy. The Shapiro-Wilk test was used to explore the data outcomes, and the result suggested the use of the parametric data test (*p*-value). Significance occurred when *p* value was less than 0.05. One-Way mixed model ANOVA repeated measurement was used to examine the significance of repeated measures in the groups and when there was significance, paired t-test was used to examine difference between the repeated measures within the same group. After completing the analysis decision support systems (DSS) research Statistical Power Calculator was used to calculate the power of the study and the result showed the power of the study at 91%, which shows an increase of the inspiratory capacity (lung volume) by 0.5 litres.

All procedures in this study followed King Fahd Armed Forces Hospital patient safety guidelines. This study was approved by King Fahd Armed Forces Hospital Research and Ethics Committee.

4.4 Results:

Thirty-six patients participated in each group (98 male (IS group= 32, CPAP2hr=31 & CPAP4hr=35) and 10 female (IS group= 4, CPAP2hr= 5 & CPAP4hr=1) with mean ages; 62 ± 9.3years). Some 26/36 participants from the "CPAP every two hours group" succeeded in re-opening the collapsed alveoli (72%), 20/36 participants from "CPAP every four hours group" succeeded in re-opening the collapsed alveoli (55%) and 19/36 participants from the "IS group" succeeded in re-opening collapse alveoli (53%). The data analysis showed no significant difference in baseline measurements for IC between all groups, but there are a significant difference in post therapy measurements. IC was increased significantly in the "CPAP every two hours group" (baseline mean for IS group 1.34L and "CPAP every two

hours group" 1.42L, post- therapy mean 1.59L and 1.88L respectively, p= 0.037) (figure 8 below).

Also, when comparing the "CPAP two hours group" with "CPAP four hours group", there was significant increase in IC in the "CPAP every two hours group" (baseline mean for CPAP 2hr 1.42L and CPAP 4hr 1.33L, post therapy mean 1.88L and 1.58L respectively, p= 0.027). However, there was no significant difference in IC between "control (IS) group" and "CPAP every four hours group" (baseline mean for IS group 1.34L and CPAP 4hr 1.33L, post-therapy mean 1.59L and 1.58L respectively, p=0.99).

There are no significant differences in baseline measured for SpO_2 between the groups. However, there are a significant differences for the post therapy measurement, SpO_2 was decreased significantly in the "IS group" as compared with "CPAP every two hours group" (baseline mean 96.67%, 96.42%, post-therapy 95.64%, 97.17% respectively, p=0.001) (figure 9 below). Also, SpO_2 was decreased significantly in the second trial group as compared with the "CPAP every two hours group" (baseline mean 97.22%, 96.42%, post-therapy 96.00%, 97.17% respectively, p=0.004). There was no significant difference in SpO_2 between control group and second trial group (p=0.569). In addition, there were no significant differences in RR and HR between all groups of therapy.

The repeated measures test result showed significance in repeated measures in IC measurements within the groups (Greenhouse-Geisser *p* value=0.001). Because there was a significant difference within the groups, paired-t test applied to examine the different in repeated measured in each group. The result showed there were no significant difference

between the baselines and 12 hours measurements in the IS (control) and CPAP4hrs groups (IS group (control) p=0.2 & CPAP4hrs p=0.7). There was a significant difference between baseline and 12 hours measures in CPAP2hrs group (p=0.009). Also, there was no significant difference between 12 hours and 24 hours measures in control and CPAP2hrs groups (p value=0.6 & 0.7, respectively). There was a significant diference in CPAP4hrs group (p=0.03). In addition, there was a significant difference between 24 hours and 48 hours measurements in CPAP2hrs and CPAP4hrs (p value= 0.001& p=0.001, respectively). However, there was no significant difference in control group (p=0.06). Moreover, there was a significant difference between 48 hours and post therapy measurements in CPAP2hrs and control groups (p value= 0.001 and p=0.001, respectively). There was no significant in CPAP4hrs group (p=0.2). There was no significant difference in repeated measures within the groups in SpO_2, HR and RR measurements.

The chest x-ray result confirmed an improvement in IC in the "CPAP every two hours group"; all successful participants had a zero category result (normal lungs) post therapy, while a baseline measurement resulted in one to two categories (mild to moderate atelectasis). Also, for most of the sputum samples, baseline measurements for all successful participants had very light to mild category result and clear or very light growth post therapy in all groups. However, some of unsuccessful participants had mild to moderate growth in sputum induction (4 participants from "CPAP every two hours group", 6 participants from "CPAP every four hours group" and 5 participants from "control group").

Most of the participants who had heavy growth in sputum induction at baseline measurements were not successful in all groups of therapies. The average hospital stay for the

"control (IS) group" was 9.5 days, "CPAP every two hours group" was 8.7 days, while the "CPAP every four hours group" was 9.0 days. There was a decrease in the hospital stay in the "CPAP 2hr group" by almost one day as compared to control group. Also, one participant from the "CPAP every two hours group" died within 30 days after the cardiac surgery, two died from the "CPAP every four hours group", while nobody died from the "control (IS) group". However, the reasons for death were related to the development of other medical conditions such as renal or cardiac complications not related to post-pulmonary complications. There were no significant differences in the mortality rate among all the groups of therapies.

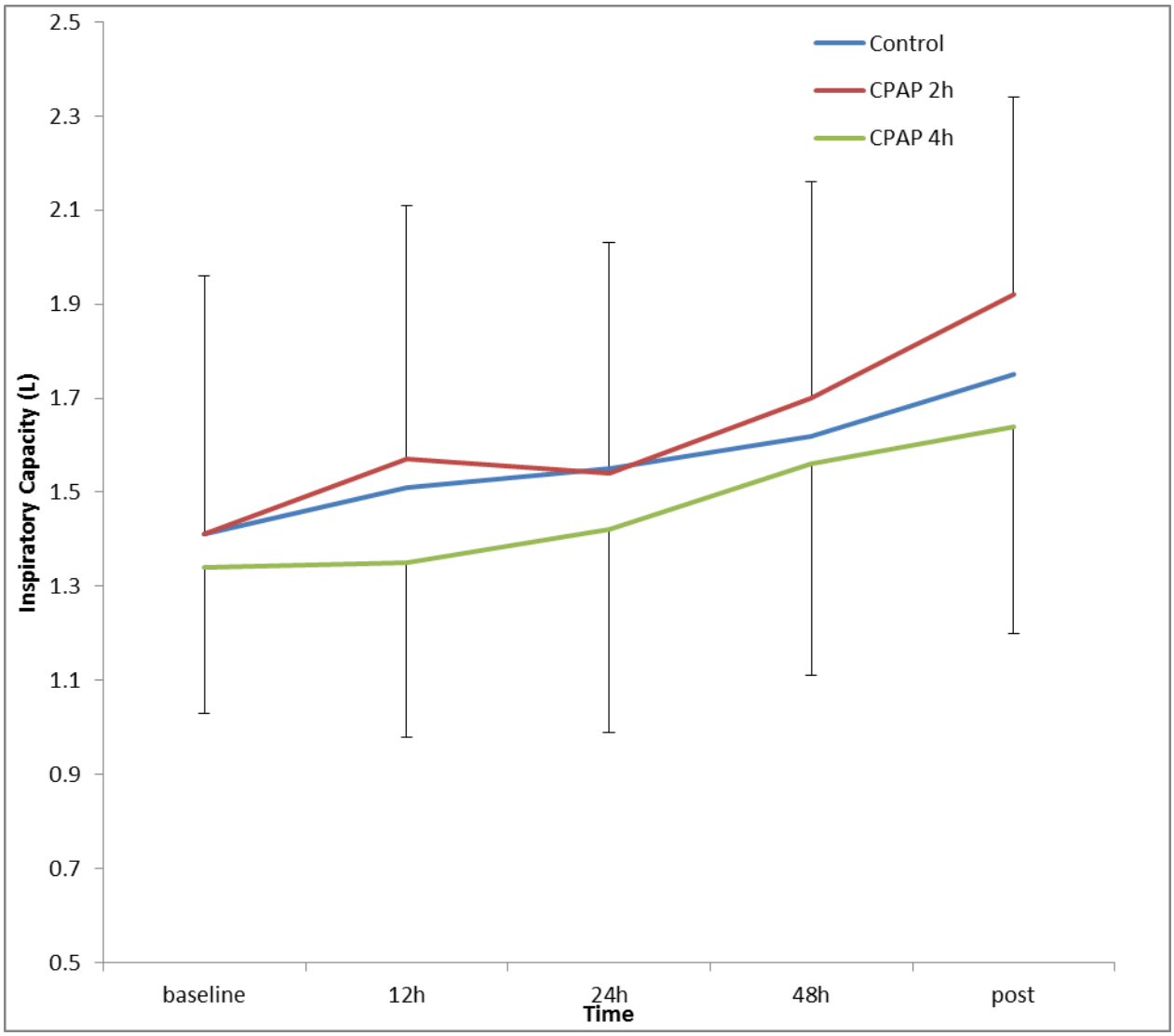


Figure 8. IC difference between CPAP every two hours therapy, every four hours and control (IS therapy) group

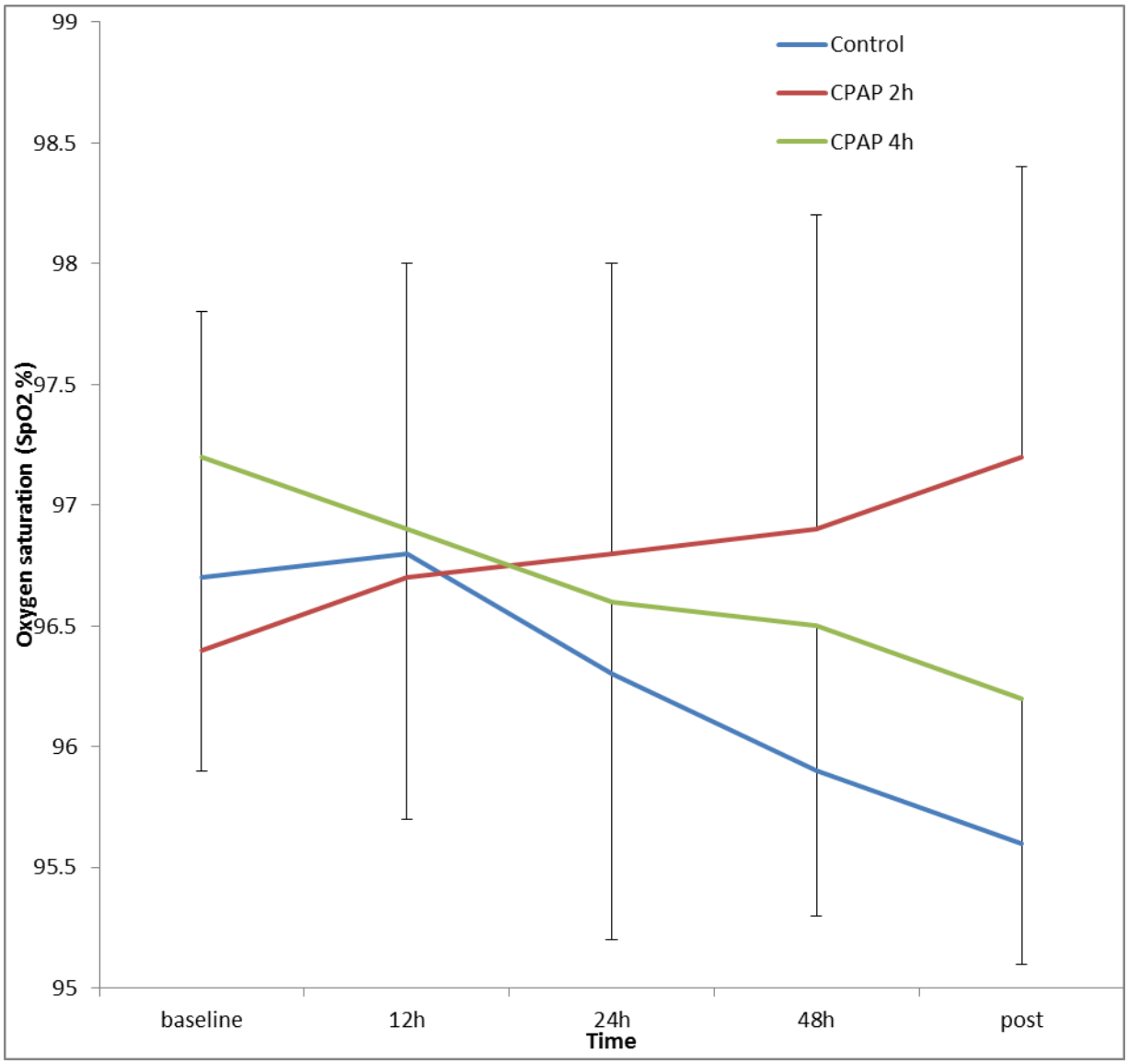


Figure 9. SpO2 difference between CPAP every two hours therapy, every four hours and control (IS therapy) group

4.5 Discussion:

The main finding of this prospective randomized study is that the early used of CPAP therapy for half an hour every two hours for post-cardiac surgery patients resulted in statistically significant improvement in treating post-surgical atelectasis, led to improved outcomes and a shorter hospital stay.

The findings of this study fail to confirm the effectiveness of incentive spirometry (IS) therapy to reduce the post-operative pulmonary complications after cardiac surgery. The previous studies showed similar result; for example, a systematic review by Overend, *et al.*, (2001), found no strong evidence to support the use of IS therapy for decreasing post-operative pulmonary complications. Also, *Freitas, et al.,* (2007) conducted randomized controlled trials to assess the effect of IS therapy in preventing post-operative pulmonary complications (such as atelectasis and pneumonia). They found that there was no significant difference between IS therapy and other therapy such as Intermittent Positive Pressure Breathing (IPPB). However, the IPPB therapy is an old method of therapy and this study uses the new stand alone system to deliver CPAP therapy. Rezaiguia and Jayr (1996) results showed an equivalent efficacy between the three therapies (IS, CPT and IPPB) while treating post-operative complications. They suggested that post-operative therapy should be continued for three to five days to prevent pulmonary complications, which agreed with the use of therapy for three consecutive days in this study.

The finding of this study showed no significant difference in CPAP2hre group in IC repeated measures between 12 hours and 24 hours. During this period of time, the chest tube is usually

being removed from the patients, which may explain this. Also, the accumulation pulmonary secretions or mucus usually come out within the first day after the surgery, particularly with smoker patients. Previous studies (Akdur, et al., 2002; Westerdahl, et al., 2005; Taylor, Dodd, Shields & Bruder, 2007; Dias, et al., 2011) showed a reduction in the lung volume after the chest tube was removed and in the first post-operative day.

The effectiveness of CPAP therapy was influenced by five main components: the type of CPAP delivery system, the period of CPAP therapy, the frequency of CPAP therapy, the interface (the type of mask use in CPAP) and the person who applies the therapy to the patient, which was confirmed clearly in this study. Despite, the importance of auto- leak compensation in the new type of CPAP delivery system, the period of CPAP therapy and the frequency used in this study is what makes the significant difference, as there is no significant difference between CPAP therapies for half an hour every four hours and IS therapy in this study. This agreed with a previous study finding that used IPPB therapy to deliver CPAP therapy and found no significant difference between IPPB therapy and IS therapy (Gale and Sanders, 1980; Celli, Rodriguez & Snider, 1984; Larsen, et al., 1994; Rezaiguia & Jayr, 1996; Overend, et al., 2001; Freitas et al., 2007). However, this study disagreed with a shorter time period and frequency of CPAP therapy used in the above studies.

The decrease in hospital stays by approximately one day for CPAP therapy every two hours group in this study will reduce the cost of cardiac surgery. The daily cost of a coronary cardiac unit (CCU) bed in hospital, where this study was conducted, was 1500 US dollars, in addition to the extra daily cost of other medical services. The reduction in cardiac surgery cost over the year for each patient will be substantial, resulting in a saving in the cardiac

surgery budget. For example, in the CPAP two hours group involving 36 participants in this study; the total cost was reduced in this group by estimated 54000 US dollars. Also, the shorter hospital stay will lead to a shorter waiting list of cardiac surgery patients. The previous studies confirm that the high incidence of post coronary artery bypass grafts (CABG) pulmonary complications can result in high mortality and increased hospital stay, which leads to an increase in the cost of the surgery (Pasquina, et al., 2003; Brooks et al., 2001; Ferguson, 1999; Lawrence, et al., 1995).

4.6 Limitation:

Due to the fact that all the participants in this study were smokers, which caused them to produce excessive secretions after the cardiac surgery, and despite the CPAP therapy in this study being applied by well-trained respiratory therapists who do their best to encourage the participants to expectorate the mucus by deep breathing and coughing, some participants still had thick mucus which required chest physiotherapy to remove the secretion. However, added chest physiotherapy was one of the failure criteria in this study, which makes removal of very thick secretion a limit in this study. Also, even with the use of very soft gel mask to deliver CPAP therapy in this study and added duoderm gel to prevent allergy-prone skin from redness, some participants who have sensitive skin will still have redness in the contact area of the nose after mask removal, especially female participants, making it uncomfortable to use it again.

4.7 Conclusion:

Early use of CPAP via mask therapy for half an hour every two hours has better outcome in reopening collapsed alveoli after cardiac surgery, especially with smokers and elderly patients. Future prospective studies are needed to assess the benefit of combined CPAP therapy with CPT which, may lead to better outcomes.

Chapter 5

Second study

5.1 Title: Difference between continuous positive airway pressure via mask therapy and incentive spirometry plus chest physiotherapy to treat or prevent post- surgical atelectasis: prospective randomized study

second study publications;

1. Abstract was presented at the 32nd International Symposium on Intensive Care and Emergency Medicine, held in Brussels from 18 to 22 of March 2012. The abstract was published in Critical Care Journal (appendix F).
2. Abstract was presented at The American Thoracic Society International Conference, held in San Francisco from 18 to 24 of May 2012. The abstract was published in Thorax Journal (appendix G)

Abstract

Objective

The most common type of acute atelectasis is post-surgical atelectasis, characterized by restricted breathing after abdominal or cardiac surgery. Large doses of opioids or sedatives, tight bandages, chest or abdominal pain, abdominal swelling (distention), and immobility of the body increases the risk of acute atelectasis following cardiac surgery. All types of therapy such as IS, coughing and breathing exercises or CPAP have a valuable role play in the prevention or treatment of acute atelectasis. However, the type of therapy that should be used is not completely clear yet. This study aims to clarify the difference of effectiveness between CPAP therapy plus chest physiotherapy (CPT) and IS therapy plus CPT to treat or prevent post-operative atelectasis.

Methods

Seventy two post cardiac surgery patients who fitted the inclusive criteria (smoker, hemodynamicly stable, the lungs are healthy and above 50 years old) participated in this study. The participants were divided randomly into two groups, the control group used IS 15 times per hour plus CPT every four hours for 3 days and the trial group used CPAP via mask (4-6 cmH_2O) for half hour every two hours plus CPT every four hours. Both regimens applied only during the waking hours. Inspiratory capacity (IC) in litres was used to compare the two groups of therapy. It was measured by an incentive spirometer after the cardiac operation as baseline-test, after 12 hours from the start of each therapy, after 24hours, 48 hours and post therapy. At the same time, respiratory rate (RR), heart rate (HR) and saturation of oxygen via pulse oximetry (SpO_2 %) were measured for both groups. Failure was defined as a need for advanced therapy such as mechanical ventilation and bi-level positive airway pressure (BiPAP). SPSS t-tests were used to examine the difference between the baseline and post therapy.

Result

36 patients participated in each group (57 male and 15 female mean ages; 54 ± 6.8 years). IC was increased significantly in CPAP group (baseline mean for control group 1.23L and CPAP group 1.41L , post- therapy mean 1.59L and 1.98L respectively, p= 0.005) (figure1). SpO2 was decreased significantly in control group (baseline 97.83%, 97.44%, post-therapy 96.56%, 97.11 respectively, p=0.037) and there was no significant difference in RR and HR.

Conclusion

Add chest physiotherapy (CPT) to CPAP via mask therapy for half an hour every two hours had better outcomes to re-open collapsed alveoli after major thoracic surgery especially in smoker and elderly patients.

5.2 Objective:

The present study was conducted after completing the first quantitative (reported in the previous chapter) which evaluated the benefits of the new methods of CPAP via mask therapy to treat or prevent post-operative pulmonary complications, mainly post-surgical atelectasis after cardiac surgery. The different frequency (every two or four hours) of CPAP via mask therapy was also evaluated in the previous study. The result showed that CPAP therapy every two hours group had better outcomes. In addition, the previous study compared CPAP via mask and IS as single therapies. The present quantitative study sought to evaluate the CPAP via mask therapy every two hours with chest physiotherapy (CPT) as a combined therapy to treat or prevent post-surgical atelectasis after cardiac surgery.

Cardiac surgery procedure especially CABG is usually associated with post-operative pulmonary complications (PPCs). These complications often lead to post-operative morbidity. When the causes of this morbidity are not treated immediately it may lead to post-operative mortality (Schuller & Morrow, 2000; Cavenaghi, Ferreira, Marino & Lamari, 2011). Post CABG patients may develop a systemic inflammatory response syndrome as a result of several causes such as reperfusion alteration in the surgical lesions and surgical trauma. Cardiac and pulmonary regions are usually mainly affected. The inflammatory cells in the pulmonary regions cause an increase in the extravascular fluid with alveoli filling, which may result in the inactivation of lung surfactant, and segmental collapse in the lung (Magnusson, et al., 1997; Renault, et al., 2009).

Despite, the dramatic improvement in CABG procedures in recent years, pulmonary functions are still the main area affected by the CABG procedures. The most common pulmonary complications after CABG are decrease in respiratory muscle strength, decreased lung volumes and post-surgical atelectasis (Johnson, et al., 1996; Westerdahl, Lindmark, Bryngelsson & Tenling, 2003). The present study concentrates on post-surgical atelectasis after CABG.

Post-surgical atelectasis is one of the most important causes of PPCs after cardiac surgery. Several studies reported the occurrences of atelectasis after cardiac surgery as up to 90% of patients (Borghi-Silva, et al., 2005; Pasquina, et al., 2004). The goal of atelectasis treatment is to re-open collapsed alveoli and remove the mucus from the lung airway. Re-opening of collapsed alveoli is usually achieved by lung expansion therapy. Moreover, there are several ways to remove the mucus from the lung airways such as coughing and huffing technique, chest percussion, chest vibrations and postural drainage (Westerdahl, Lindmark, Almgren & Tenling, 2001; Pryor, et al., 2008).

In the case of thick and dry mucus, it usually required additional mucus break down medication as inhalation therapy is needed. The removal of lung mucus technique is called chest physiotherapy (CPT). The abbreviation (CPT) was used in the present study (Placidi, et al., 2006). The previous study in this research project compared the different frequency of CPAP via mask therapy with IS therapy each as a single therapy. The present study evaluates the benefits of adding chest physiotherapy to both therapies as a combined therapy.

Chest physiotherapy (CPT) is a very important technique to remove mucus or secretions from the lung airways. Usually, the removal of mucus from lung airways leads to easy opening of the collapsed alveoli (atelectasis) after CABG by lung expansion therapy. There are several types of CPT techniques used to remove the mucus from the lung airway. The present study used CPT technique according to AARC guidelines (2011).

Chest Physiotherapy / Postural Drainage techniques:

Chest physiotherapy refers to several techniques used to prevent the accumulation of secretions or to mobilize the secretions once they are present. The objectives of chest physiotherapy are to aid in bronchial hygiene, improve the efficiency and distribution of ventilation and improve cardiopulmonary reserve through physical training. This procedure has been commonly referred as chest physiotherapy, chest physical therapy, postural drainage and percussion and percussion and vibration (Gosselink et al, 2000; AARC 2011).

5.2.1. Chest Percussion:

Principle of Chest Percussion;

1. Chest percussion is a therapeutic technique used in conjunction with postural drainage to loosen adherent bronchial secretions.
2. This is done by using cupped hands to “clap” the chest wall, trapping air between the hand and the chest wall.
3. The sudden compression of air produces an energy wave which is transmitted through the chest wall tissues to the lung tissues. This energy wave, theoretically loosens

tenacious mucus plugs and facilitates the movement of secretions by gravity and cough.

Chest percussion technique can be applied by hand or chest physical therapy machine. The hand percussion technique is applied with hands in a cupped position, the wrists are alternately flexed and extended using cupped hands to strike the chest wall rhythmically. Most of the motion should come from the wrists. The upper arms and shoulders should remain relaxed throughout the procedure.

Proper clapping makes a hollow sound and is not painful. The period of percussion should be between 1.5 to 2 minutes, over the segmental group being drained. It can be used with adult and paediatric patients. The present study used the physical therapy machine to apply the chest percussion technique.

The indications of percussion technique are to prevent accumulation and to improve mobilization of bronchial secretions. The contraindications are pulmonary haemorrhage, when a patient suffers from "brittle bones", bony metastases, undrained empyema and if the patient is nauseated. Moreover, percussion should only be performed over the thoracic cage. It should never be performed over the spine or below the thoracic cage, as this can cause injury to the spinal column or internal organs. The goals of the percussion technique are to improve the mobilization of thick, tenacious bronchial secretions and to prevent the accumulation of bronchial secretions (Langenderfer, 1998; AARC practice guidelines 2011).

5.2.2. **Postural drainage:**

Principle of postural drainage;

Postural drainage assists the normal clearing mechanism of the lungs in moving secretions from the small bronchi into the main bronchi, so that it may be removed by coughing or tracheal suctioning. Gravity is used to aid in the mobilization of secretions, so the segments involved must be higher than the bronchi through which the secretions pass to reach the trachea. Also, the position of patient will be determined by the segment involved. Segments involved are determined by auscultation and chest X-ray.

The indications of postural drainage are to prevent accumulation and to improve the mobilization of bronchial secretions. The contraindications are patient with shortness of breathing, unstable vital signs, directly after meals, neurosurgical patient and quadriplegic patient. Postural drainage position is the most important component that leads to success of the technique. Modification of positioning may be required based on patient tolerance and specific medical problem (Langenderfer, 1998; Gosselink et al., 2000; AARC; bronchial hygiene practice guidelines, 1991).

The most significant lung segments demanding postural drainage are:

a) Left upper lobe and lingular segment.

b) Right middle lobe, lateral and medial segments.

c) Right and left lower lobes and posterior basilar segments

The period of postural drainage treatment session should be maintained for 3 to 5 minutes in each position. In addition, the therapeutic goals are to improve the mobilization of bronchial

secretions and to prevent the accumulation of bronchial secretions (Langenderfer, 1998; Gosselink et al, 2000; AARC: bronchial hygiene practice guidelines, 1991).

The combined therapy method was used by several studies in the past to evaluate the benefits and to treat or prevent post-operative pulmonary complications. The study by Westerdahl and colleagues (2001), evaluated the effectiveness of three types of therapies to improve pulmonary function and post-operative atelectasis after cardiac surgery. The three therapies were deep breathing exercise (DBE) with blow bottle-device, DBE with an inspiratory resistance-positive expiratory pressure mask (IR-PEP) (the previous two therapies as a combined therapy) and DBE therapy as a single therapy. The pulmonary function values improved significantly in the first combined therapy group (DBE with blow bottle-device) as compared to DBE therapy alone. However, there was no significant difference between the second combined therapy group and the other group. Also, chest physiotherapy was applied to all participants once or twice daily after the cardiac surgery. The present study applied CPT every four hours during the waking hours in the hospital.

Crowe and Bradley (1997), evaluated the effectiveness of combined therapy (IS therapy with physical therapy) to reduce PPCs, mainly atelectasis after CABG, as compared to physical therapy alone. The physical therapy included breathing exercise, lung mucus removal technique and mobility. The results showed no difference between the two groups in reducing post-surgical atelectasis. However, the type of patients that were evaluated had chronic obstructive airways disease with airflow limitation. The present study evaluated patients with healthy lungs.

Borghi-Silva and colleagues (2005) evaluated the effectiveness of positive end expiratory pressure (similar to CPAP via mask therapy) with physical therapy intervention (as combined therapy) to improve pulmonary function and inspiratory muscle strength after CABG. The physical therapy intervention included chest percussion, vibration, postural drainage and patient mobilization. The results showed that the combined group had improving pulmonary function values and inspiratory muscle strength on the fifth post-operative day as compared to first post-operative day as compared to the physical therapy group alone.

Gosselink, *et al.,* (2000), evaluated the relative effectiveness of combined therapy (IS with chest physiotherapy) and chest physiotherapy alone to prevent PPCS after thoracic surgery. Chest physiotherapy includes breathing exercise, huffing and coughing techniques. The results showed no difference between the two approaches in preventing pulmonary function reduction and improving post-surgical atelectasis.

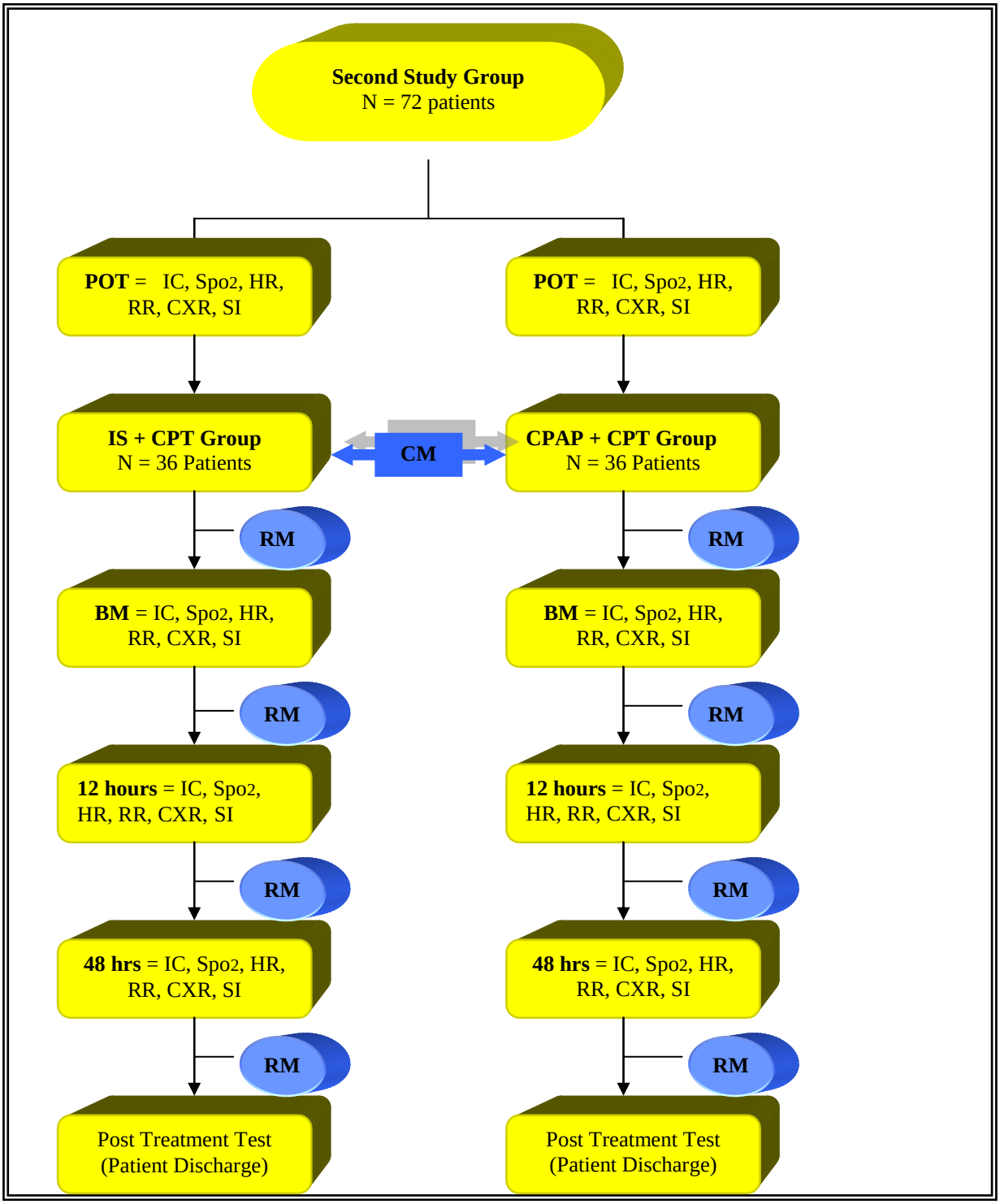
There was difference in the effectiveness of adding chest physiotherapy to lung expansion therapy in the previous studies regarding preventing or improving PPCs particularly post-surgical atelectasis after thoracic or cardiac surgery. The methods used to apply chest physiotherapy were different. Moreover, the frequency of chest physiotherapy was different. The present study used the chest physical machine to apply chest physiotherapy which includes chest percussion, chest vibrations and postural drainage. The advantages of chest physical machine are that it can apply chest percussion and vibrations together, it can control the level of pressure applied to the patients, it is easy use and comfortable for the patient.

The present study aims to evaluate the effectiveness of adding chest physiotherapy to CPAP via mask therapy to treat or prevent post-surgical atelectasis as compared to Incentive spirometery therapy with chest physiotherapy. The study design is summarised in figure 10.

5.3 Method:

The present quantitative study recruited participants from the patients scheduled for cardiac surgery in King Fahd Armed Forces Hospital in Jeddah, Saudi Arabia from April 2011 to September 2011. This study sample size significant followed the previous study sample size in this research project, which required at least 32 participants in each group to be significant. The patients who agreed to participate in the study came to the hospital to sign the consent form and read the participant's sheet before the cardiac surgery (see appendix H).

Eighty five participants agreed to enroll in the study; however nine of them were excluded as they developed one or more of the exclusion criteria after the cardiac surgery and four participants declined to participate after the surgery. Seventy two post cardiac surgery patients who met the inclusion criteria (smoker, haemodynamically stable, healthy lungs and above 50 years old) participated in the study. Patients who had massive atelectasis (more than 50% of alveolar collapse), predicted mortality rate more than 30% (depending on pre-surgery patient assessment), those who had undergone repeat cardiac surgery, severe pulmonary edema, severe bleeding (more than 100ml per hour), history of chronic lung disease, unstable angina, and contraindication for CPAP or IS therapy were excluded.



Abbreviations:

BM – Baseline Measurement
CM – Comparison Measurement
CPAP – Continuous Positive Airway Pressure
CXR – Chest X-Ray
CPT – Chest Physiotherapy
HR – Heart Rate
SI – Sputum Induction
PTT – Post Treatment Test
RR – Respiratory Rate
RM – Repeated Measurement
Spo_2 - Oxygen Saturation in arterial blood content
VC – Vital Capacity
POT- Pre-operatiive test

Figure 10. Second Study Design

The participants were divided randomly into two groups; IS plus CPT group used IS therapy (Respiflo 5000 incentive spirometer manufactured by Tyco Healthcare Group LP in Mansfield, Massachusetts, USA) 15 times per hour plus chest physiotherapy (CPT) every four hours (CPT applied by G5- Vibramatic Machine by General Physiotherapy Inc, USA) and CPAP2hr plus CPT group used CPAP via mask (4-6 cmH_2O) (the type of CPAP delivery system used in this study was ResMed VPAP III manufactured in Milton, Australia) for half an hour every two hours plus CPT every four hours. Each group used the therapy for three days after extubation during the waking hours in the cardiac unit (usually from 6 a.m to 8 p.m).

Inspiratory capacity (IC) (maximum volume of air inhaled after a normal expiration) measured in litres was used to compare the two therapy regimes. IC was measured by an incentive spirometer (Respiflo 5000 incentive spirometer manufactured by Tyco Healthcare Group LP in Mansfield, Massachusetts, USA) and was used to confirm the accuracy and reliability of IC measurements. The participants were asked to repeat the test three times and the largest volume was taken. It was measured after the cardiac operation as a baseline-test, after 12 hours from the start of each therapy, after 24hours, 48 hours and post therapy.

At the same time, Respiratory Rate (RR), Heart Rate (HR) and Saturation of Peripheral Oxygen (SpO_2 %) (Saturation of Arterial Oxygen is a ratio expressed as a percentage of the volume of oxygen carried, to the maximum volume that can be carried, by the haemoglobin and measured by a pulse oximeter device) were measured for all groups. Also, chest x-ray was performed to confirm the improvement or the prevention of post-surgical atelectasis (categorized as zero= normal, 1= mild, 2= moderate or 3= severe atelectasis) and sputum

induction (a procedure to obtain deeply coughed-out sputum) was taken to diagnose chest infection or pneumonia (categorized as zero= no growth, 1= mild, 2=moderate or 3= heavy growth).

Failure was defined as a need for advanced therapy such as mechanical ventilation and Bi-level Positive Airway Pressure (BiPAP). In addition, secondary end points consisted of length of stay in hospital and 30 days mortality.

SPSS version 18.0 was used for the analysis of data and independent t-test was used to examine the differences between the baseline and post therapy data. The Shapiro-Wilk test was used to explore the data outcomes, and the result suggested the use of the parametric data test (*p*-value). Significance occurred when *p* value was less than 0.05. Also, paired t-test was used to examine the difference between the repeated measures within the group.

All procedures in this study followed the King Fahd Armed Forces Hospital patient safety guidelines. This study was approved by King Fahd Armed Forces Hospital Research and Ethics Committee.

5.4 Results:

Thirty-six patients participated in each group (57 male and 15 female mean ages; 54 ± 6.8 years). Some 30/36 participants from CPAP2hr plus CPT group (CPAP every two hours therapy plus CPT) succeeded in re-opening the collapsed alveoli (83%) whereas only 22/36 participants from IS plus CPT group (IS therapy plus CPT) succeeded in re-opening collapsed alveoli (61%). IC was increased significantly in the CPAP2hr plus CPT group

(baseline mean for IS plus CPT group 1.23L and the CPAP2hr plus CPT group 1.41L, post-therapy mean 1.59L and 1.98L respectively, p= 0.005) (figure 11 below).

SpO_2 was decreased significantly in IS plus CPT group as compared with CPAP2hr plus CPT group (baseline 97.83%, 97.44%, post-therapy 96.56%, 97.11% respectively, p=0.037). However, there were no significant differences in RR and HR between the two therapies (figure 12 below).

The repeated measures result showed significant (p=0.001) increased in CPAP2hr plus CPT group IC measured between the baseline and 12 hours measurements. However, there was no signicant (p=0.14) in IS plus CPT group measurements. There was no significant in IC measures between 12 hours and 24 hours in both groups (CPAP2hr plus CPT group p=0.25 & IS plus CPT group p=0.78). There was a significant increased in IC between 24 hours and 48 hours measures in both groups (CPAP2hr plus CPT group p=0.003 & IS plus CPT group p=0.001). In addition, there was a significant increased between 48 hours and post therapy measurements in IC variable in both groups. However, the increased in CPAP2hr plus CPT group more than other group (CPAP2hr plus CPT group p=0.001 & IS plus CPT group p=0.02). There was no significant difference in repeated measures in SpO_2, HR, and RR variables in both groups.

The chest x-ray results confirmed an improvement in IC in CPAP2hr plus CPT group; most (90%) of successful participants had a zero category result (normal lungs) post therapy and other three successful participant had less than mild atelectasis after surgery, which is

accepted in their condition. Their chest x-ray baseline measurement showed one to two categories (mild to moderate atelectasis).

The sputum sample result in this study was better than the previous study results in this research project. This is due to adding chest physiotherapy, which means better lung airways clearance. Almost all successful participants in this study had clear or very light growth category result of the sputum samples post therapy, while baseline measurements result were very light to mild category in both groups. However, some of the unsuccessful participants had mild to moderate growth in sputum induction (three participants from CPAP2hr plus CPT group and four participants from IS plus CPT group). Moreover, there was a relationship between the growth and the thickness of the sputum and the success of the therapy. This explained why most of the participants who had heavy growth in sputum induction at baseline measurements were not successful in either of the therapies.

The average hospital stay for IS plus CPT group was 9.2 days, while the CPAP2hr plus CPT group was 8.4 days. There was a decrease in the hospital stay in CPAP2hr plus CPT group by almost one day as compared to IS plus CPT group. Also, one participant from each of the groups died within 30 days after the cardiac surgery. However, the reasons for death were related to the development of other medical conditions such as renal or cardiac complications not related to post-pulmonary complications. There were no significant differences in the mortality rate among both groups of therapies.

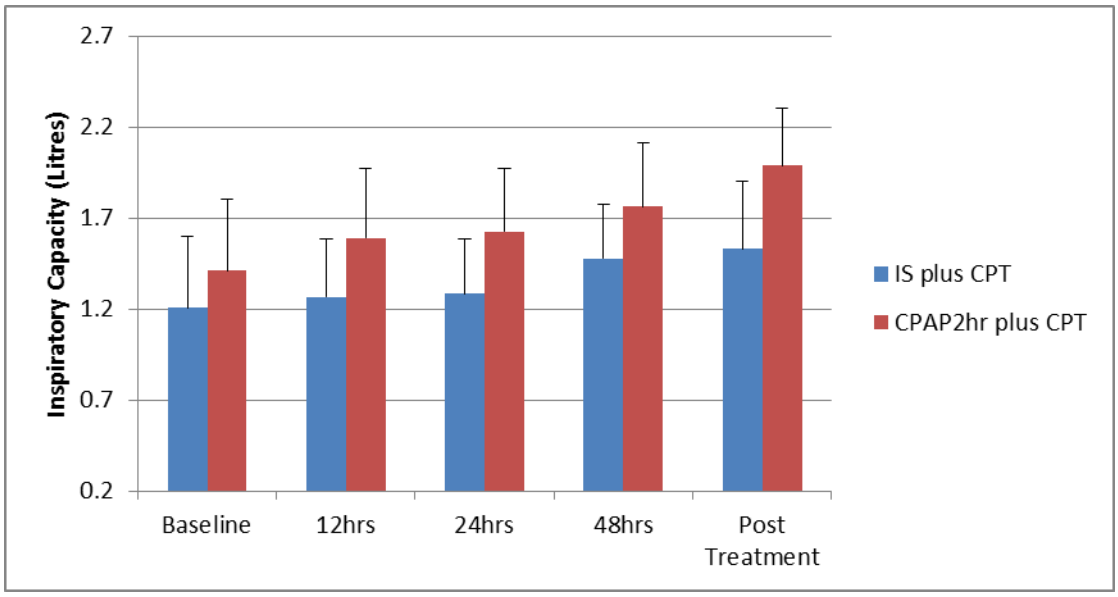


Figure 11. The inspiratory capacity difference between CPAP via mask therapy every two hours plus CPT and IS therapy plus CPT (control plus CPT)

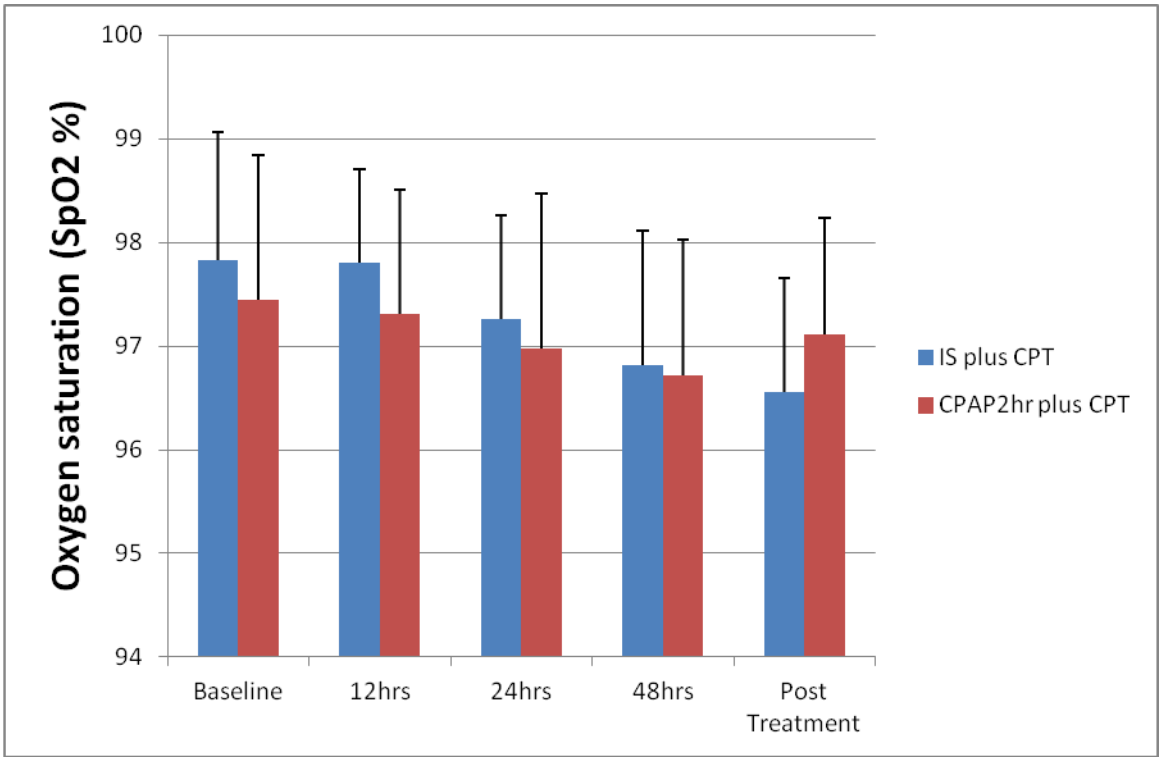


Figure 12. The oxygen saturation difference between CPAP via mask therapy every two hours plus CPT and IS therapy plus CPT (control plus CPT)

5.5 Discussion:

The main finding of this prospective randomized study is that adding chest physiotherapy technique to CPAP via mask therapy for half an hour every two hours for post-cardiac surgery patients resultes in statistically significant improvement in treating post-surgical atelectasis, which leads to improved outcomes and a shorter hospital stay.

The findings of this study fail to confirm the effectiveness of adding chest physiotherapy to incentive spirometry (IS) therapy to reduce the post-operative pulmonary complications, mainly atelectasis, after cardiac surgery. The previous studies showed a similar result; for example, Crowe and Bradley study (1997), found out that there was no difference between IS plus physical therapy intervention and chest physical therapy alone in reducing post-surgical atelectasis. Also, another study (Gosselink, et al., 2000) result showed no difference between IS therapy plus chest physiotherapy and chest physiotherapy alone in preventing pulmonary functions values reduction and improving atelectasis after thoracic surgery.

The present study agreed with the results presented by Borghi-Silva, *et al.*, (2005). They found that the combination of positive end expiratory pressure (another form of CPAP via mask therapy) and physical therapy intervention were more effective than physical therapy intervention alone in improving pulmonary function values and inspiratory muscle strength after CABG. Usually, the improvement in post-operative pulmonary function values was associated with post-operative atelectasis improvement. However, the present study showed a different result regarding when the improvement occurred; Borghi-Silva, *et al.*, (2005) study showed improvement after the fifth post-operative day, while in the present study it occurred after the third post-operative day.

The effectiveness of chest physiotherapy is influenced by the frequency of the therapy and the type of chest physiotherapy technique used. The present study used the complete technique of CPT, which includes chest percussion, vibrations, postural drainage and mobilization. The chest physiotherapy applied by CPT machine ensured equal application to all participants.

The present study agreed with the earlies study (Borghi-Silva, et al., 2005) which used the complete technique of CPT (such as chest percussion, vibrations, postural drainage and mobilization) and found the therapy to be more effective. However, the present study disagreed with another study (Westerdahl, et al., 2001) which used CPT once or twice daily after the surgery. In the present study CPT frequency was every four hours for better effectiveness.

The use of CPT machine to applied CPT technique seems better than the use of hand to apply it. This is due to the CPT machine applies chest percussion and vibrations at the same time, while the hands technique applies them separately. Also, CPT machine applies the therapy in the same waves and pressure, while the hands technique depends on the person applying the therapy, which often differs from person to person. The present study used CPT machine to applied CPT therapy and found out that the combined therapy is more effective in treating post-surgical atelectasis. The other studies found that hand technique was not effective (Crowe and Bradley, 1997; Gosselink, et al., 2000).

Moreover, the decrease in hospital stays by approximately one day for CPAP2hr plus CPT group in the present study will reduce the cost of cardiac surgery. The daily cost of a

Coronary Cardiac Unit (CCU) bed in hospital, where this study was conducted, is 1500 US dollars, in addition to the extra daily cost of other medical services. The reduction in cardiac surgery cost over the year for each patient will be substantial, resulting in a saving in the cardiac surgery budget. The shorter hospital stay will lead to a shorter waiting list of cardiac surgery patients. The previous studies confirm that the high incidence of post coronary artery bypass grafts (CABG) pulmonary complications can result in high mortality and increased hospital stay, which leads to an increase in the cost of the surgery (Brooks, et al., 2001, Ferguson, 1999, Lawrence, 1995).

5.6 Limitation:

Due to the fact that all the participants in this study were smokers, which caused excessive secretions after the cardiac surgery, and despite the use of chest physiotherapy technique in this study, which reduced the excessive secretions, there were limitations as compared to the first study. Some participants still had thick mucus which required humidification to break down the mucus. However, the CPAP therapy machine used in this study does not have humidification, which makes removal of very thick secretion a limit in this study. Also, application of CPAP therapy without humidity caused dry mouth in some participants. However, this limitation can be avoided partly, by drinking water after the therapy.

In addition, even with the use of very soft gel mask to deliver CPAP therapy in this study, and adding duoderm gel to prevent allergy-prone skin from redness, some participants who had sensitive skin still had redness in the contact area of the nose after mask removal, especially female participants, making it uncomfortable to use again.

5.7 Conclusion:

Adding chest physiotherapy (CPT) to CPAP via mask therapy for half an hour every two hours had better outcomes to treat or prevent acute atelectasis after major thoracic surgery, especially in smokers and elderly patients.

Chapter 6

Third study

6.1 Title: Post cardiac surgery patients' experiences using continuous positive airway pressure (CPAP) via mask therapy to treat post-surgical atelectasis.

Third study publications;

1- Abstract has been accepted to be presented at The American Thoracic Society International Conference, which will be held in Philadelphia from 17 to 23 of May 2013 (appendix I).

ABSTRACT

Objective

Cardiac surgery procedure especially CABG is usually associated with post-surgical atelectasis. CPAP via mask therapy is one of the intervention treatments to re-open collapsed alveoli (atelectasis) after cardiac surgery.

This study aims to evaluate the compliance and periodicity of CPAP via mask therapy use to treat or prevent post-surgical atelectasis after CABG.

Methods

Sixty two post cardiac surgery patients who used CPAP via mask therapy every two or four hours were invited to participate in this study. All the participants used CPAP machine in the first three post- cardiac surgery days during waking hours. The participants were given a questionnaire to answer before hospital discharge. The questionnaire was composed of items about the compliance, the periodicity of CPAP therapy use and the side effects of the CPAP mask used such as pain over bridge of the nose, dry mouth, allergy or teeth and gum pain. Also, the questionnaire was linked to informal open-end question to clarify the patient's history of these illnesses before the use of CPAP therapy.

Result

Sixty two patients participated in this study from the two difference frequency group (CPAP therapy every two or four hours) with response rate approximately 85%. Twenty seven males and three females belonged to the CPAP2hr group (ages; 58 ± 6.4 years). Twenty eight males and four females were in the CPAP4hr group (ages; 57 ± 7.2 years). All the participants started to use CPAP therapy in the first post-operative day immediately after extubation from mechanical ventilation. No one from either of the groups suffered from nose bleeding, excessive sneezing, eczema or asthma either before or after therapy. More than half of the participants (60%) complained a dry mouth after the therapy. Twenty eight participants (93%) from CPAP2hrs group reported treatment compliance from CPAP machine use and 27 participants (84%) in CPAP4hrs group.

Conclusion

The result showed high acceptance rate of compliance toward CPAP therapy use especially in CPAP2hrs group.

6.2 Objective:

The present study was conducted after the two previous quantitative studies that evaluated the benefits of early use of CPAP therapy in preventing or treating atelectasis after CABC. This study aimed to evaluate the patients' compliance and periodicity about CPAP therapy. A questionnaire was prepared to gather data on the experiences of the patients respondents before hospital discharge.

Cardiac surgery procedure especially CABG is usually associated with post-surgical atelectasis. CPAP via mask therapy is one of the intervention treatments to re-open collapsed alveoli (atelectasis) after cardiac surgery. The type of CPAP via mask therapy that was employed in this study is originally used to keep the upper airway open in obstructive sleep apnea (OSA) syndrome patient.

Several previous studies measured the compliance and periodicity of CPAP therapy used in patients with OSA (Zozula & Rosen, 2001; Nolan, Ryan, Oconnor, & McNicholas, 2006; Bakker, Campcell & Neill, 2010). The results showed patients' compliance and acceptance rate was between 47 and 91%. However, those studies measured the compliance for long term OSA patients. The time of CPAP therapy in OSA studies was more than 6 hours per night continuously. In the present study the CPAP therapy was used for a short periods of time (half hour), which may increase the patient's compliance and acceptance rate.

McArdle and colleagues (1999) evaluated the components influencing the long term CPAP therapy use in 1, 211 long term patients. Only 4.5% of the patients refused the CPAP therapy,

mostly female and current smoker. Moreover, 20% of the patients stopped the therapy after using it for a short period of time at home. The patients' compliance acceptance rate within five years was 68%. The main components influencing the compliance acceptance rate for CPAP therapy were the number of hours use, the patient tolerance in the first three months and patient judgment of lack of benefit from CPAP therapy.

CPAP via mask therapy increases functional residual capacity (FRC) and reflexly increases the opening of upper airway (the pharynx) by generating a positive pressure in the main airway (Kryger, 2005). It is usually considered as first line treatment to treat the OSA syndrome patient. However, some OSA patients refuse to use CPAP via mask therapy for several reasons such as inconvenient and bulky nature of the therapy (Richard, et al., 2007), patient not well understand the therapy benefits (Smith, Nadig & Lasserson, 2009), CPAP machine noise and uncomfortable mask (Chai, Pathinathan & Smith, 2006).

The present study aimed to evaluate the compliance and periodicity of CPAP via mask therapy used to treat or prevent post-surgical atelectasis after CABG. It also, assesses the patients' compliance in two different frequency of CPAP therapy (CPAP therapy every two hours and every four hours). A questionnaire was used in this study to evaluate the patient compliance, periodicity and side effects of CPAP via mask therapy (see appendix J).

6.3 Method:

The present study was conducted in King Fahd Armed Forces Hospital in the Kingdom of Saudi Arabia from March 2010 to March 2011. All participants in the previous quantitative study (first study) who used CPAP via mask therapy every two or four hours were invited to

volunteer. They were given a questionnaire to answer before discharge from the hospital. All participants had used the latest version of CPAP delivery system (ResMed VPAP III manufactured in Milton, Australia). In addition, they used the most comfortable gel face mask available in the market. The levels of CPAP delivery pressure were set between 4 to 6 cmH_2O.

All the items in the questionnaire were explained in detail by respiratory specialist to all voluntear participants in this study. In addition, all participants signed a consent form after they read and understand all the questions (see appendix K). All the participants were reminded to complete the questionnaire one day before hospital discharge.

The type of questionnaire used in the study was a structured and open-ended question. The questionnaire in gathering data was modified from a valid and reliable questionnaire. It has been used by Kalan, Kenyon, Seemungal & Wedzicha, (1999) to evaluate the CPAP therapy compliance and side effect in patients with OSA. Also, the questionnaire was translated to Arabic language from English by official guaranteed translation company. Moreover, it has been used by Saudi Thoracic Society for several years with sleep apnoea patients to evaluate the CPAP therapy compliance.

The questionnaire was composed of items about the compliance and the periodicity of CPAP therapy use. It also includes questions regarding the side effects of the CPAP mask used such as pain over bridge of the nose, dry mouth, allergy or teeth and gum pain. Other questions related to side-effects and symptoms associated with CPAP therapy use such as sneezing, dizziness, running nose or sore eyes. In addition, the questionnaire was linked to informal

open-end questions to clarify the patient's history of these illnesses before the use of CPAP therapy.

6.4 Results:

The purpose of the present study was to evaluate and compare the responses of compliance and periodicity of CPAP therapy use. A questionnaire was made for the participants in order to determine CPAP therapy compliance to treat or prevent atelectasis in two different frequencies (two and four hours after cardiac surgery). The questionnaire examined the physiological effects, the side effects of CPAP machine and benefits related to CPAP therapy use in different frequency of time.

6.4.1 Demographics:

Thirty from thirty six participants in CPAP2hr group completed and returned the questionnaire before hospital discharge. Thirty two from thirty six participants in CPAP4hr group completed and submitted the questionnaire. Some of the respondents did not complete the questionnaire for the following reasons: three patients were in a hurry to leave the hospital, four patients refused to complete the questionnaire, one patient required advanced therapy, two patients did not answer due to lack of time, despite several reminders to complete it one day before discharge.

Sixty two patients participated in this study from the two difference frequency group (CPAP therapy every two or four hours) with response rate approximately 85%. Twenty seven males and three females belonged to the CPAP2hr group (ages; 58 ± 6.4 years). Twenty eight males and four females were in the CPAP4hr group (ages; 57 ± 7.2 years). All the participants had

started to use CPAP therapy in the first post-operative day immediately after extubation from mechanical ventilation.

6.4.2. Physiological effects:

All the participants used CPAP machine in the first three post- cardiac surgery days during waking hours (usually from 6 AM to 8 PM). CPAP2hrs group used CPAP therapy every two hours approximately eight times daily (four hours daily). Daily use of CPAP therapy in CPAP4hrs group was 50% time of CPAP2hrs group. No one from either of the groups suffered from nose bleeding, excessive sneezing, eczema or asthma either before or after therapy. One participant in each group (1/30 in CPAP2hrs group & 1/32 in CPAP4hrs) complained about nasal block before the therapy which was solved after the therapy. More than half (58%) suffered from dizziness before CPAP therapy. However, the dizziness decreased significantly in both groups, four patients from CPAP2hrs and five patients from CPAP4hrs group (approximately 16% had post therapy dizziness).

Of the 32 participants in CPAP4hrs group 11 suffered from dry nose after the therapy while 13 participants suffered from it in CPAP2hrs. One third of the participants (33%) in both groups complained about dry mouth before CPAP therapy. However, more than half of the participants (60%) complained a dry mouth after the therapy. In addition, some participants reported reduction in mucus 31% in CPAP2hrs group and 14% in CPAP4hrs after the therapy as compared to pre-therapy complained. One patient suffered from pain over bridge of nose in CPAP2hrs group after therapy while no one complained of it in CPAP4hrs group. The

summary of physiological effect relating to CPAP therapy every two hours or every four groups is shown in figures 13 and 14 respectively.

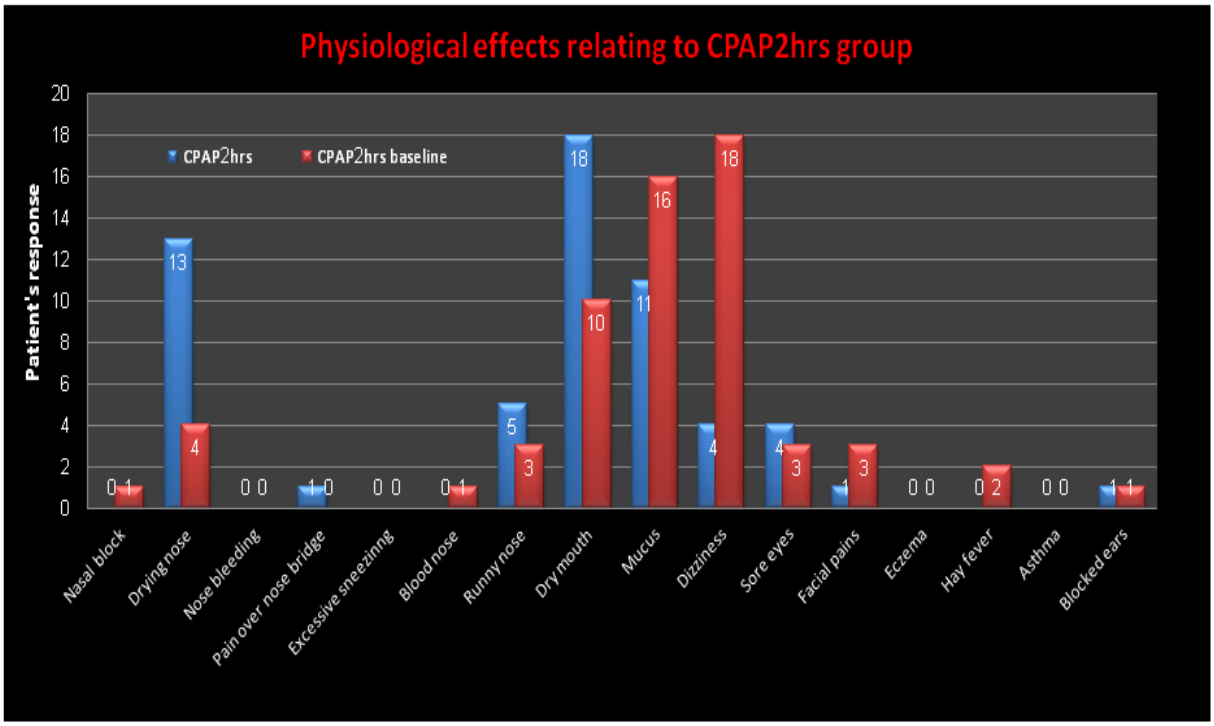


Figure 13. Physiological effects relating to CPAP therapy every two hours.

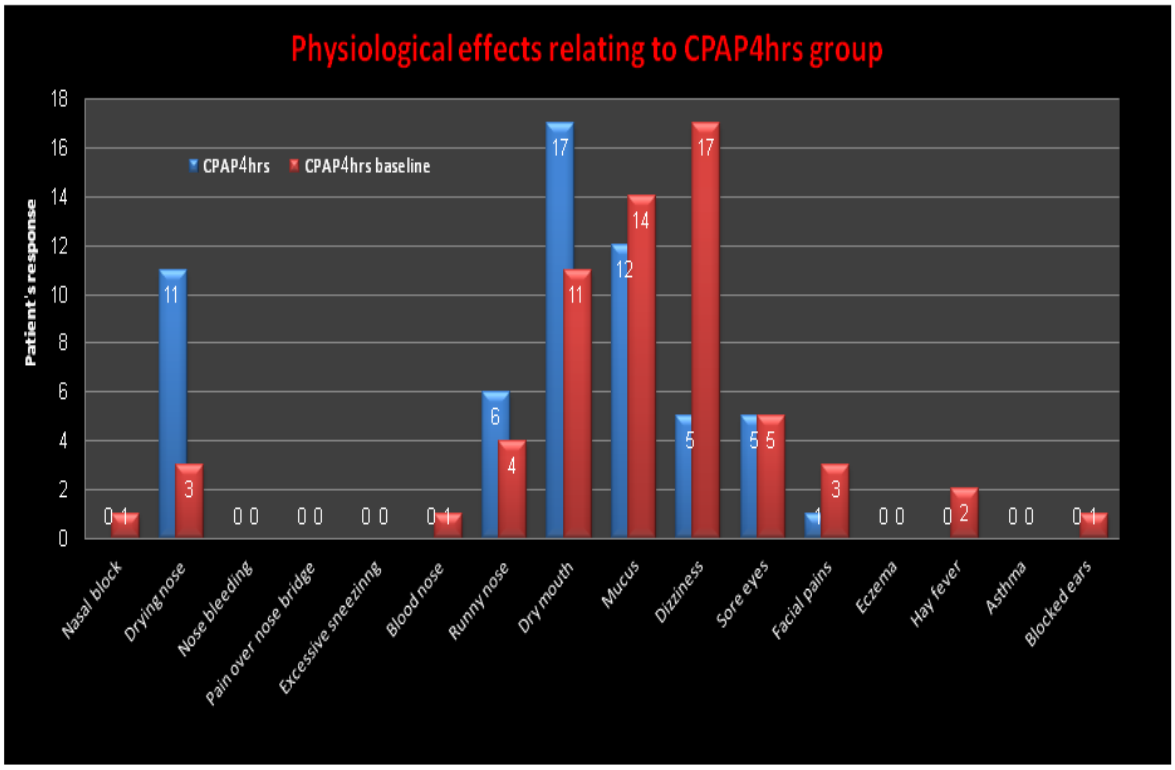


Figure 14. Physiological effects relating to CPAP therapy every four hours.

Two participants (7%) from CPAP2hrs group complained about the noise of the machine while four participants in CPAP4hrs group were irritated by the noise. More than half of the participants (53%) in both groups complained that the mask was uncomfortable. Five participants (17%) reported air leak from face mask in CPAP2hrs group and eight participants (25%) in CPAP4hrs. However, the complaints about breakdown of skin over nose (i.e. Pressure sore) in CPAP4hrs group were marginally less than CPAP2hrs (15% in CPAP4hrs and 16% in CPAP2hrs).

Almost all, 28, participants (93%) from CPAP2hrs group reported treatment benefit from CPAP machine use and 27 participants (84%) in CPAP4hrs group. The result showed high acceptance rate of compliance toward CPAP therapy use especially in CPAP2hrs group. The summary of the participants' responses in CPAP machine side effects and benefits for CPAP2hrs group is shown in figure 15 and CPAP4hrs group in figure 16.

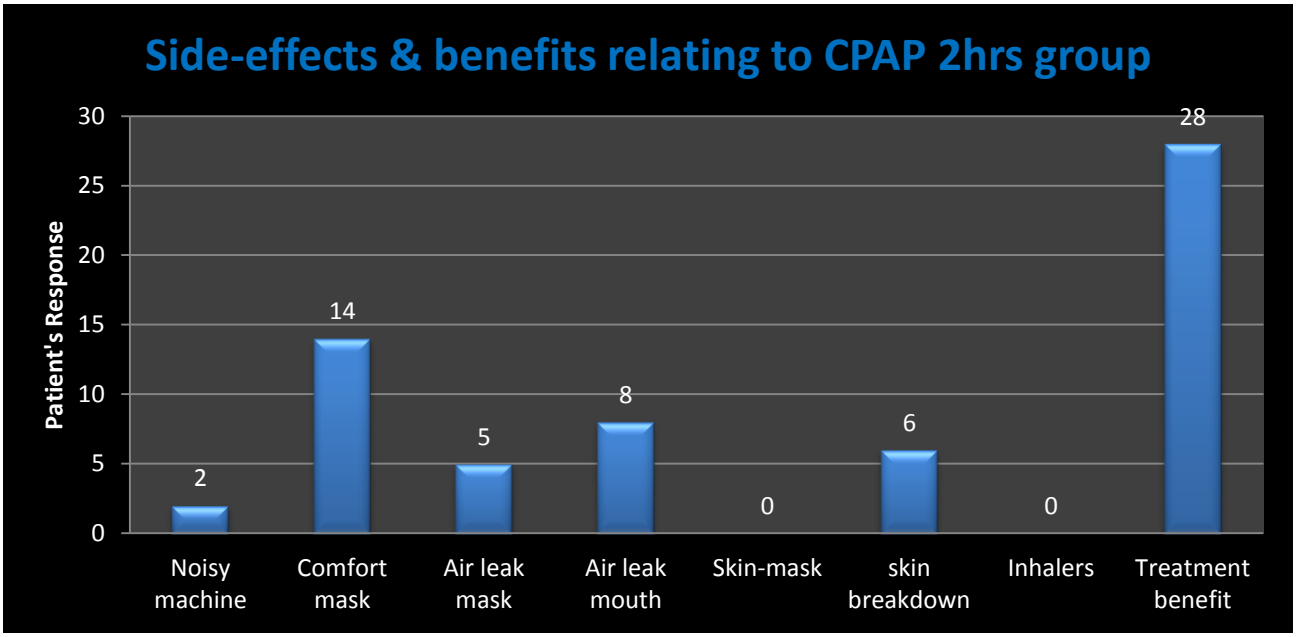


Figure 15. CPAP machine side-effects and benefits relating to CPAP therapy every two hours

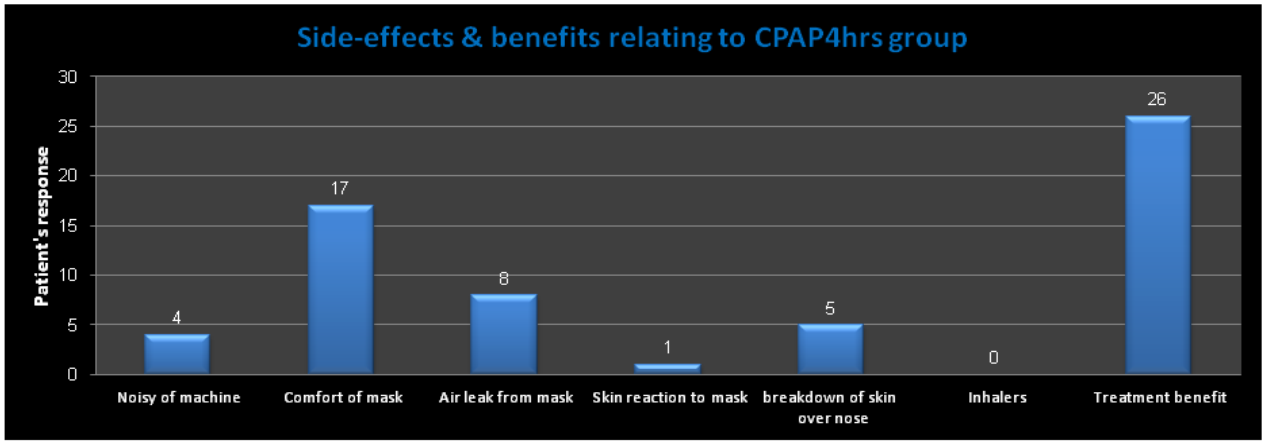


Figure 16. CPAP machine side-effects and benefits relating to CPAP therapy every four hours.

6.5 Discussion:

This is the first study that evaluates the compliance and periodicity of the use of CPAP therapy to treat or prevent atelectasis after cardiac surgery. It also examines the side effects and symptoms relating to CPAP device use. The results showed high acceptance rate of CPAP therapy use in both groups in most of the responses. However, CPAP therapy applied for half hour every two hours had a better acceptance rate than CPAP therapy use every four hours (93% and 84% respectively).

The high compliance of CPAP therapy use found in the present study agreed with the previous studies of (McArdle, et al., 1999; Kakkar & Berry, 2007). This was also supported by the previous study (Montserrat, et al., 2001; Weaver, et al., 2007) that found out the increase of time in using CPAP therapy was associated with the increase in compliance rate. There was high incidence of dry mouth and nose in the present study because there was no humidification system use in CPAP machine. The heated or cold humidity would likely lead to a decrease in the side effects of dry nose or mouth during the CPAP use and potentially better compliance.

According to the study of Massie and colleagues (1999), the use of a humidity system with CPAP therapy significantly ($p=0.001$) decreased the frequent complaint of dry mouth or nose. Also, the use of humidification system with CPAP via mask therapy has been recommended as standard of practice to reduce dry mouth and nose (Kushida, et al., 2006). However, the improvement of the compliance associated with humidification use still not clear according to the study (Gay, Herold & Olson, 2003; Kakkar & Berry, 2007). The present study found out that more than 60% of the participants in both group complained of

dry nose or mouth that agreed with the earlier study reported that 65% of patients complained also with dry nose or mouth (Ryan, Doherty, Nolan & McNicholas, 2009).

The types of mask use with CPAP therapy is usually associated with better patient compliance. The present study used the most comfortable gel face mask available in the market. The result showed that more than half complained about an uncomfortable mask in both groups. However, the present study disagreed with another earlier study (Ryan, Garvey, Swan, Behan & McNicholas, 2011) which recommended the use of nasal mask. Due to several reasons, the nasal mask increase the air leak of mouth by 50%, allergy to the face (Pepin, et al., 1995) and the mouth leak associated with lower compliance (Baltzan, Elkholi &Wolkove, 2009; Sopkova, Dorkova & Tkacova, 2009).

Compliance or adherence studies usually concentrate on pharmaceutical not mechanical therapy such as CPAP therapy. However, the improvement of CPAP technology using smart card, which can save and report data (such as CPAP hours use and the level of CPAP pressure). This can make the CPAP therapy adherence measurement better than medication measurement (Weaver & Grunstein, 2008).

Several factors relate to predictors of CPAP therapy use compliance;

First factor, the type of mask (full face, oral, nasal or nasal pillows mask) used with CPAP therapy (Beecroft et al. 2003). The present study used the most comfortable face gel mask to improve the patient adherence for CPAP therapy.

Second factor, patient's characteristics (such as age and sex) may not influence the CPAP therapy compliance. However, the acceptance of CPAP therapy by different ethnic groups is still not clear. Several studies reported non-white patients (for example, African Americans) had lower acceptance for CPAP therapy than American whites (Budhiraja, et al., 2007; Scharf, Seiden, DeMore & Carter-Pokras, 2004; Joo & Herdegen, 2007). The present study evaluated the acceptance of CPAP therapy in Saudi patients and found a high acceptance rate. However, the CPAP therapy was used for a short period of time and there was no comparison for other ethicities. For the above reasons, the acceptance of CPAP therapy by different gender and ethnicity requires further future research to determine the extent of these factors.

Third factor, the severity of disease as reported in several studies may influence the CPAP therapy adherence (Gay, Weaver, Loube & Iber, 2006; Budhiraja, et al., 2007). For example, in OSA patients, there is increase in the day time sleepiness associated with long use of CPAP therapy (Hollandt & Mahlerwein, 2003). However, the severity of day time sleepiness reduces the effectiveness of this factor to CPAP therapy become less (Barb, et al., 2001). Other studies (Nakata, et al., 2005; Sugiura, et al., 2007) result showed the nasal resistance or obstruction significantly (more than 50%) influence the initial acceptance of CPAP therapy. The present study investigated the CPAP therapy acceptance in post-operative cardiac patients which may not influence the CPAP therapy adherence as much as with patients with OSA.

Fourth factor, even with the use of advanced CPAP technology and the most comfortable mask there were still some patients' reporting side effects of CPAP therapy. Several studies (Engleman & Wild, 2003; Weaver, 2001) reported more than 50% side effect of CPAP

therapy user. However, there was no evidence that prevents the use of CPAP therapy due to the side effects reported by patient. The present study used all elements (such as advance CPAP system technology and comfortable mask) to avoid or minimize the side effects of CPAP therapy use. However, all treatments provided to patients showed that there will be a few side effects.

Fifth factor, the type of method used to introduce the CPAP therapy. The clear explanation and pre-use demonstration of CPAP devices to respondents will lead to increase the patient compliance of CPAP therapy (Means, Edingr & Husain, 2004). In the present study, the investigator explained the CPAP therapy in detail in simple terms to all participants before the cardiac surgery. Also, the participants were allowed to experience the CPAP therapy before the cardiac surgery under the supervision of the researcher.

6.6 Limitation

One of the most frequent side effect with CPAP therapy use was dry mouth and nose, due to the CPAP devices used in this study does not have humidification system. This study used the most comfortable gel mask available in the local market. However, still a lot of the participants complained about the mask not comfortable to them. The use of high comfortable modern mask may resolve this problem.

6.7 Conclusion:

Post-CABG patient accepting rate about the CPAP via mask therapy use was very high and CPAP every two hours more preferable to them. Resolution of the usual side effect of CPAP therapy use such as dry mouth and uncomfortable mask may increase the compliance rate in the future.

Chapter 7

Fourth study

7.1 Title: The experience of medical staff about the use of CPAP via mask therapy to treat or prevent post-surgical atelectasis after CABG.

Fourth study publications;

1- Article will be submitted from this study to Critical Care Nursing journal.

Abstract

Objective

Lung expansion therapies are usually used to treat or prevent post- surgical atelectasis after cardiac surgery. The type of lung expansion therapy used was different in most of the hospital that has cardiac surgery procedure all over the world. This depends on the availability of the therapy in the hospital and the acceptance of medical staff to use it.

The present study aims to evaluate the medical staff experiences regarding the use of CPAP therapy to treat or prevent post-surgical atelectasis after CABG.

Method

This study was conducted at King Fahd Armed Forces Hospital between September 2011 and December 2011. An e-mail letter was sent through the hospital intra-net mail system that invited all relative medical staff to participate in this study. Inclusion criteria in selecting the participants of this study are: (1) medical staff who worked with the new method of CPAP therapy for more than 3 months (2) worked in cardiac unit or ward (3) able to read and understand English language.

A personal semi-structured (face to face) interview for 30 minutes was used to gather the medical staff experiences in this study. The interviews were documented by the investigator and recorded by audio-tape.

Result

Fifty four letters were sent via intra-net e-mail to all registered e-mail for all medical staff working in the cardiac unit or ward at King Fahd Armed Forces Hospital. Forty two replied to the invitation e-mail with response rate of 77%. Eleven males and 19 females participated in the study. Of thirty participants were 9 cardiac doctors, 5 cardiac nurses and 16 cardiac respiratory therapists.

When the participants were asked a question about if they worked with the new method of CPAP therapy before twenty four of the participants (80%) had not worked with it before. Most of the participants (26/30) had agreed to use the new way of CPAP therapy to treat or prevent post surgical atelectasis after CABG. In addition, thirteen of participants (43%) said CPAP therapy required less patient effort than IS therapy.

Conclusion

There was a high accepting rate (86%) of the new method of lung expansion therapy (CPAP via mask therapy) to treat or prevent post- surgical atelectasis by the participating medical staff.

7.2 Objective:

The first and the second studies in this research project evaluated the benefits of early use of CPAP via mask therapy to treat or prevent post-surgical (CABG) atelectasis. The third study used structured questionnaire in evaluating the patients' experiences about CPAP via mask therapy. This present study focused on evaluation of the medical staffs experiences about CPAP via mask therapy used to treat or prevent atelectasis after cardiac surgery.

Lung expansion therapies are usually used to treat or prevent post- surgical atelectasis after cardiac surgery (Herdy, et al., 2008). The type of lung expansion therapy used is different in the many hospitals that has cardiac surgery procedure all over the world. This depends on the availability of the therapy in the hospital and the acceptance of medical staff to use it (Zarbock et al, 2009 & Agostini et al, 2009).

The medical staff understanding of lung expansion therapies used is an important component that leads to an acceptance of the type of therapy used (Reeve, Denehy & Stiller, 2007). The experience of medical staff regarding the type of lung expansion therapies in use has been evaluated by several studies in the past (Tucker, et al., 1996; Overend, et al., 2010; Fiore, Chiavegato, Paisani & Colucci, 2010).

In the survey study conducted by Overend and colleagues (2010), they interviewed via phone physiotherapists regarding the post-operative lung expansion therapy used in 18 different Canadian hospitals performing cardiac surgery procedure. The result showed that 38% of the surveyed hospitals (7/18) used pre-operative respiratory therapy. Most (89%) of the hospitals

used different types of post-operative lung expansion therapies (16/18). Deep breathing and coughing exercise was used in 16 hospitals, while incentive spirometry (IS) therapy was used in 7 hospitals. Moreover, approximately two thirds of the surveyed hospitals provide cardiopulmonary rehabilitation such as mobilization out of the bed, and lower or upper-extremity exercises.

Another study (Reeve, Denehy & Stiller, 2007) evaluated, via a questionnaire, the current practice of respiratory therapy management in 46 hospitals performing thoracic surgery in Australia and New Zealand. The results revealed that most of the hospitals (44/46) used post-operative respiratory therapy, while more than half (63%) used pre-operative prophylactic respiratory intervention. Post-operative respiratory interventions (lung expansion therapies) were used in most of the hospitals (80%). The most common method used was deep breathing and coughing exercise, post-operative respiratory rehabilitation, sustained maximal inspiration (IS) and forced expiration methods.

The recent survey study in Sweden (Westerdahl & Olsen, 2011), evaluated the experience of 29 physiotherapists working in different cardiac centres in Swedish hospitals regarding the post-operative lung expansion therapy used. All of them used post-operative breathing exercise with patients after cardiac surgery while 19 (73%) of them used pre-operative respiratory therapy methods. Most of them (83%) used deep breathing exercise (DBE) with positive expiratory pressure (PEP) device is usually their first choice, while deep breathing exercise alone was used by the entire group of surveyed physiotherapists. In addition, all of them suggested the use of deep breathing exercise with or without PEP every hour during the

first two post-operative days while 19 of them suggested continuing performing DBE until the patient is discharged from the hospital.

The choice of lung expansion therapies was influenced by three main factors: literature recommendations, medical staff experience and the availability of the technique or established practice according to Reeve, Denehy & Stiller, (2007). The requirement for further investigation to identify the best type of lung expansion therapies to treat or prevent post-operative pulmonary complications was suggested by two studies recently (Reeve, Denehy & Stiller, 2007; Overend, et al., 2010).

The medical staff experience regarding the use of CPAP via mask therapy as a type of lung expansion therapies to treat or prevent post-operative pulmonary complication (especially post-surgical atelectasis) after cardiac surgery has not previously been evaluated.

The present study aimed to evaluate the medical staff' experiences regarding the use of CPAP therapy to treat or prevent post-surgical atelectasis after cardiac surgery by using semi-structured interviews.

7.3 Methods:

The investigator conducted the previously reported quantitative studies about the benefits of CPAP via mask therapy use to re-open collapsed alveoli (atelectasis) after cardiac surgery at King Fahd Armed Forces Hospital in Saudi Arabia for almost two years. The medical staff experiences about the new approach of CPAP via mask therapy used were evaluated by the present qualitative study. It was conducted at King Fahd Armed Forces Hospital between September 2011 and December 2011. An e-mail letter was sent through the hospital intra-net

mail system that invited all relevant medical staff to participate in this study. Inclusion criteria in selecting the participants of this study are: (1) medical staff who worked with the new method of CPAP therapy for more than 3 months (2) worked in cardiac unit or ward (3) able to read and understand English language.

Research interviewing method is a conversation between the researcher and the interviewee. However, there is a purpose for research conversation questions; they allow the researcher to elicit statements or facts from participants (Bleakley, 2005).

The degree of the structure used in the interview method usually identifies the type of the interview. There are three types of interviews - structured, semi-structured and unstructured. The structured interview uses the same type of questions and the same way of questioning with all the participants and is usually used in market research.

The interviewer, in a semi-structured interview, uses the major questions in the same order with all participants. However, the sequence of the questions asked by the interviewer and the probes used may differ for each participant to gather more information and enrich the data. The unstructured interview uses a cocktail of questions, which the interviewer can put forward depending upon the interviewee's response. (Gilbert, 2008).

The semi-structured interview is a research method most widely used, particularly in health care research. It is commonly used to provide extensive professional knowledge about personal experience. The present study used semi-structured interview to gather knowledge about the experience of medical staff toward CPAP therapy used after cardiac surgery in the hospital (Adams, McIlvain & Lacy, 2002).

The two ways of performing the interview can be either as group or individual (face-to-face) interview. Face-to-face interview provides in-depth information and that is why it used in this study. Communication is the activity of passing information through messages, information or exchange of thoughts by behaviour, visual, speech, writing or signals. There are two important principles regarding research interview communication. First, in order to achieve natural information, the open ended type of question should be used as often as possible. Second, the techniques of questioning should encourage interviewee to elaborate their beliefs and attitudes and avoid non-committal direct answers (Gilbert, 2008).

The two ways to encourage the interviewee to answer the research questions are prompting and probing. Prompting is used to encourage the interviewee to answer within the framework of the structured interview. Probing is used to encourage the interviewee to answer the question in full detail and this is generally used in non-structured interview. The researcher should encourage the participant to share and gather data in the participant's own words as much as possible without leading them. This should be the interviewer's goal (Jonhson, 2002).

A personal semi-structured interview was used to gather the medical staff' experiences in this study. The investigator used a written guide of key questions during the interview. The interview consisted of primarily open questions, which allowed the medical staff to answer the questions freely about their experiences of each therapy (Gerrish & Lacey, 2010) (see table 2 below). The interviews were documented by the investigator and recorded by audio-tape.

The medical staff were interviewed for approximately 30 minutes about their experiences regarding the use of the CPAP therapy. To ensure the privacy of the conversation, the interview took place in the staff meeting room in CCU unit for all the staff who worked in CCU unit, and to the staff meeting room in cardiac ward for all the staff working in the cardiac ward. All participants signed a consent form as an agreement to participate in the study (see appendix L). The study was approved by King Fahd Armed Forces Hospital Research and Ethics Committee.

Table 2 . The interview questions

1- What is your medical back ground and how many years of experience do you have in the post-cardiac surgery field? 2- Have you worked with the new methods of CPAP therapy before? If yes, please explain. 3- In your opinion, what is the difference between the new methods of CPAP therapy and the regular IS therapy to prevent or treat post-cardiac surgery atelectesis? 4- Would you agree to use the new methods of CPAP therapy with your patients in the future? If your answer is NO, please explain why. 5- In your opinion, what are the advantages and the disadvantages of the new CPAP methods of therapy to treat or prevent post-cardiac surgery atelectasis? 6- Do you prefer to use CPAP therapy every two hours or every four hours? 7- Do you think the new methods of CPAP therapy are easy to understand and use?

7.4 Results:

Fifty four letters were sent via intra-net e-mail to all registered medical staff working in the cardiac unit or ward at King Fahd Armed Forces Hospital. Forty two replied to the invitation e-mail with response rate of 77%. Eight respondents were excluded because they did not fit the inclusion criteria. Four apologized and decided not to participate in the study.

Table 3 presents the demographic data of the participants. As presented in the table 3, 11 males and 19 females participated in the study. Of thirty participants were 9 cardiac doctors, 5 cardiac nurses and 16 cardiac respiratory therapists.

Table 3. Demographic data of the participants

Medical Specialty	**Gender**		**Sub-specialty**	**Years of experience**			**Total**
	Male	Female		**>5**	**>3**	**>2**	
Doctor	7	2	Cardiac surgeon: 1 Cardiac intensivist: 3 Cardiac registrar: 5	4	3	2	9
Nurse	1	4	Cardiac registered nurse: 5	3	2	0	5
Respiratory therapist	3	13	Cardiac respiratory therapist: 16	6	5	5	16
						Total	**30**

Thematic content analysis was used to analyse the interviews. The four major themes were recognized: 1) the medical staff back ground, 2) their opinion in the new way of therapy, 3) their agreement to continue using it in the future and 4) what type of CPAP therapy they prefer (Braun, & Clarke, 2006).

7.4.1. Medical staff background:

The medical staff' background and the years of experience are very important component in relating to post-operative pulmonary complications after cardiac surgery. Those who have more experience had usually worked with most types of lung expansion therapies and they knew the advantages and the disadvantages of each therapy. As appeared in Table 3, the participants had worked with cardiac patients after CABG and worked for at least three months with the new way of lung expansion therapy (CPAP via mask therapy). Thirteen participants (43%) had more than five years of experience and 10 of them had more than three years experience (33%). While, only 7 participants (23%) had more than two years experience.

In addition, the present study interviewed medical staff from different background such as doctor, nurse and respiratory therapist, who could observe the benefits of CPAP via mask therapy used from different aspects (see examples of medical staff interview in appendix M).

"D 5: I am an intensivist (MRCP) working in Post Cardiac Surgery ICU and had ten (10) years experienced"

"N 2: I am a registered nurse in CCU for six (6) years"

"R 1: I'm working as RT since 1988 and I've been working with post cardiac surgery patient for 17 years"

When the participants were asked a question about if they had worked with the new method of CPAP therapy previously. Twenty four of the participants (80%) had not work with it before. One of the participants revealed that she had not used the CPAP therapy as the new way but used it as a non-invasive treatment. Five of the participants (16%) tried CPAP therapy as last choice when the other therapies (such as IS and DBE) were not successful. However, they did not previously use it exactly as the new way of routine therapy, the time period and frequency of the therapy was different.

"R 4: NO, only for non-invasive treatment"

"R 1: Yes, we used the CPAP therapy before for post-operative patient to keep the lungs open when the other therapies are not successful as a last choice before the use of the advance therapy"

7.4.2. Medical staff opinion in the new way of therapy:

When the participants were asked a question about their opinion on the new way of CPAP via mask therapy used to prevent or treat post-cardiac surgery atelectasis and if there was a difference between it and the regular (IS) therapy. Most of the participants (26/30) had agreed to use the new way of CPAP therapy. Of 30, two participants were not totally in agreement, while two participants (6%) said they believed that there is no difference from IS therapy.

In addition, the medical staff perception revealed that there were three main differences received between the two therapies. Thirteen of participants (43%) said CPAP therapy required less patient effort than IS therapy. Five of them (16%) thought CPAP therapy is more effective. While, three participants (10%) preferred CPAP therapy because it can be used while the patient is sleeping. However, the other participants had different range of reasons for the use of CPAP therapy such as better with smoker patient, better oxygenation, you can set the desired pressure and did not require a lot of patient explanation.

> *"D 8: CPAP therapy is most effective as a positive pressure therapy to prevent atelectasis"*
>
> *"N 5: In a new CPAP therapy, patient exerts less effort; while IS therapy needs more effort"*
>
> *"R 1: In CPAP therapy patient doesn't need to exert effort just to open up their lungs. The machine will help to keep the lungs open even if they are in pain since this is the most common cause of atelectasis and most of the patient able to sleep and tolerate this new method. While, in IS therapy, if the patient is in their old age, it's hard for them to do IS well since their pain threshold is low compare to the young ones. And sometimes, most of them are complaining that they don't want to do it because they want to sleep"*

"D 9: I feel there is no big difference between new methods of CPAP therapy and usual CPT and IS therapies in prevention of post-surgical atelectasis"

"R 4: In CPAP therapy, you need to set a desired pressure, depending on the patient's chest X-ray in order to improve their lungs, while in IS, you only need patient who can follow the proper way of doing it"

7.4.3. Medical staff agreement to continue using the CPAP therapy in the future:

The participants were asked a question about their agreement to continue using the new way of CPAP via mask therapy to treat or prevent post-surgical atelectasis. Most of the participants (28/30) agreed to continue to use it in the future. However, one of the participants disagreed to use it as a regular basis and one also disagreed to use it as first choice of therapy.

"D 9: Yes, but not as a regular basis I prefer to use it only in patient who doesn't respond well to CPT and IS therapy"

"R 2: Yes, I definitely agree to use the new methods of CPAP therapy to our patients in the future"

"R 13: I think the use of IS and CPT therapy is more effective for patient who are able to perform IS therapy, but for patient who are too old or cannot tolerate, IS therapy. Also, patient who is bed ridden CPAP therapy is more useful"

The participants enumerated three main advantages of CPAP via mask therapy. First, it improves or prevents post-surgical atelectasis (17/30). Second, it improves oxygenation (9/30). Lastly, there is less effort exerted by the patient (23%). On the other hand, the participants enumerated three disadvantages of using CPAP via mask therapy: gastric distention (11/30), not effective in patient with more lung secretion (4/30), patient dry mouth (10%).

> *"D 4: the advantages of CPAP therapy used are preventing or improving atelectasis and very easy to be used at bedside without consumption of patient effort and without inducing pain. Disadvantages, not effective in patients with a lot of secretion who needs chest physiotherapy and cough exercise with CPAP therapy"*

> *"N 1: Advantages of CPAP therapy used are less effort to be taken by the patient and more effective in treating atelectasis. The disadvantages are hard to apply on noncompliant patient and gastric distention"*

> *"R 6: Advantages of CPAP therapy used are improving oxygenation, prevent atelectasis and increase residual capacity. The disadvantages are gastric distention, can cause hypotension and uncomfortable to the patient"*

7.4.4. What type of CPAP therapy frequency they prefer:

The number of participants were almost divided into half on which frequency of CPAP via mask therapy they prefer. Of thirty, 16 participants (53%) preferred to use CPAP therapy every two hours. Fourteen of them (46%) preferred to use the CPAP therapy every four hours.

"D 3: I preferred to use the CPAP therapy every two hours according to the severity of the case"

"N 4: I preferred to use CPAP via mask therapy every two (2) hours"

"R 2: I prefer to use CPAP therapy every four hours to give continuous time of therapy, less disturbance to patient and more rest to the patient"

In addition, the participants were asked a question about how easy to use and understand the new way of CPAP via mask therapy. All participants agreed that it was simple to use the therapy and it is easy to understanding it.

"D 6: Yes, it is easy to be used and understood"

"N 3: Yes, it is simple to be used"

"R 2: Yes, as respiratory therapist, the new methods of CPAP therapy are easy to understand and use as long as we know how to operate the machine and the patient is cooperative"

7.5 Discussion:

The major finding of the present study was high accepting rate (86%) of the new method of lung expansion therapy (CPAP via mask therapy) to treat or prevent post- surgical atelectasis by the participating medical staff. Most of the participants agreed to continue using the new method in the future. More than half of them (53%) preferred to use CPAP therapy every two hours, while the rest of them preferred to use it every four hours. In addition, the major advantage of using CPAP therapy was improving or preventing post-surgical atelectasis (57%), while the major disadvantage was gastric distention (36%).

The participants of the present study were medical staff from different backgrounds. They are doctors, nurses and respiratory therapists who were engaged in the new method of therapy. They were involved in the study to evaluate the new method of lung expansion therapy. This study was different from the previous studies that included participants from one type of medical background only (Reeve, Denehy and Stiller, 2007; Overend, et al., 2010; Westerdahl & Olsen, 2011). The result of the present study showed that most of the participants agreed to the use of lung expansion therapy to treat post-operative pulmonary complications after cardiac surgery and this was supported by a previous study. A qualitative study by Reeve, Denehy and Stiller, (2007), showed that post-operative respiratory interventions (lung expansion therapies) were used in most of the hospitals (80%).

Another qualitative study by Overend, *et al.,* (2010), found out that most (89%) of the hospitals used different type of post-operative lung expansion therapies after cardiac surgery. Likewise, the recent study (Westerdahl & Olsen, 2011), revealed that all the participants used post-operative breathing exercise with patients after cardiac surgery.

Furthermore, the importance of the post-surgical atelectasis as one of the most commonly occurring of post-operative pulmonary complications appeared clearly in this study. The result showed that 57% of the participants suggested the advantage of CPAP therapy used was to improve or prevent post-surgical atelectasis and this was related with the previous study. However, the present study disagreed with the other study (Westerdahl & Olsen, 2011) that suggested the use of DBE therapy as first choice to treat post-operative pulmonary complications, due to most of the participants suggesting the use of CPAP via mask therapy as first choice.

Moreover, the present study result showed that 36% participants were concerned about the gastric distension as a result from CPAP via mask therapy used. This was supported by the previous study results in this research project, which showed that more than half of the patients complained about gastric distension. However, this problem likely to be resolved by adjusting the flow rate and the desired set of pressure.

7.6 Limitation:

The present study focused on the evaluation of the medical staff' experience about CPAP via mask therapy used to treat or prevent atelectasis after cardiac surgery. It was limited in involving participants from one hospital only, not like the other study which included several hospitals. For this reason, the findings cannot be generalized as advice in medical practice. Future research will need to include the other hospitals in the country which has cardiac surgery procedure. This will lead to better outcomes and understanding of the best lung expansion therapy to be used.

7.7 Conclusion

Most of the participated medical staffs have positive perception in relation to the used of CPAP via mask therapy to improve or prevent post-cardiac surgery atelectasis. However, the participants' perception regarding the best frequency (every two or four hours) of CPAP via mask used is unclear. Further investigating research on this topic that will include the different hospitals in the country is recommended.

Chapter 8

Research discussion and conclusion

8.1 Research discussion

This research project contains four studies. All studies evaluated the benefit of early use of CPAP therapy to treat or prevent post-surgical atelectasis after CABG. To the best of the author's knowledge, the present research is a pioneer research nationally, as well as internationally for evaluating the effectiveness of CPAP via mask therapy in this particular method, duration and frequency, using the latest technology of CPAP machine and modern soft interface (the mask). The effectiveness of CPAP therapy was compared with the best method of IS therapy, as documented by previous studies.

There has been an improvement in non-invasive cardiac revascularization procedures, such as stents and balloon angioplasty over the last two decades. This has led to a reduction in invasive cardiac procedures. As a consequence, most of the CABG procedures are now performed on elderly patients, with medical co-morbidities. Moreover, the techniques of cardiac invasive procedures have improved lately by using off pump, minimally invasive procedures (Mack, et al., 2004; Northrup, et al., 2004).

Despite these improvements in CABG procedure, post-operative pulmonary complications (PPCs) are still the major concern of the cardiac surgeons and medical staff involved in post-operative care. This is because PPCs usually result in increased morbidity and mortality, and also increased hospital stay. (Wynne & Botti, 2004). PPCs include hypoxemia, pneumonia

and post-surgical atelectasis. Post-surgical atelectasis is the most frequent complication after CABG. It has a high frequency of occurrence after CABG, ranging from 54% to 92% (Stock, et al., 1984; Vargas, et al., 1993; Pasquina, et al., 2004).

Lung expansion therapies (IS, DBE, IPPB, PEP, NIV & CPAP) have been used to treat or prevent PPCs since the advent of the CABG procedure (Stock, et al., 1985; Gosselink, et al., 2000; Pasquine, et al., 2003; Freitas, et al., 2007; Zarbock, et al., 2009; Urell, et al., 2011). However, IS therapy and DBE are the most frequently used therapies after CABG nowadays (Overend, et al., 2010; Westerdahl & Olsen, 2011). IS therapy is the standard therapy used for lung expansion in the hospital where this research was conducted, and for this reason it has been used as a control group. IS therapy is subject to patient cooperation. The most uncooperative patients after CABG are smokers and elderly patients. The present research focuses on this sub-group of patients.

The present research used a mixed methods of studies. The first two studies were intervention quantitative studies, which investigated the benefit of CPAP via mask therapy. The others were qualitative studies that evaluated the experience of patients and medical staff regarding CPAP therapy use.

The first study in this research compared CPAP via mask therapy for half an hour at two different frequencies (every two hours or every four hours) against a regular IS therapy, as a control group. The result showed a significant increase in mean inspiratory capacity (IC), measured post therapy, by almost half a litre in CPAP every two hours group as compared to the measured baseline. This improvement in lung volume is usually associated with

improvement or reduction in post-surgical atelectasis. This finding agrees with previous studies which found strong association between the lung volume improvement and improvement of atelectasis (Stock, et al., 1985; Linder, Lotz & Ahnefeld, 1987; Lenique, et al., 1997).

Also, the first study finding showed a significant increased in oxygen saturation (SpO_2) in CPAP two hours group in post therapy measured as compared to baseline measure (baseline mean 96.42%, post-therapy 97.17%). This improvement in SpO_2 confirmed the effectiveness of CPAP therapy in treating post-surgical atelectasis, due to the association between atelectasi and hypoxemia. For example, when the atelectasis improves the hypoxemia improves also. This finding agreed with previous study (Pasquina, et al., 2004; Zarbock, et al., 2009; Urell, et al., 2011) found association between improve in hypoxemia and post-surgical atelectasis .

The finding of the first study showed IS therapy was less effective in improving or preventing post-surgical atelectasis, particularly in this sub-group of patients (smokers and elderly patients) after CABG. This finding agreed with the previous studies, which found IS therapy was less effective in improving post-surgical atelectasis after cardiac surgery (Overend, 2001; Freitas et al., 2007). However, the author of the present study would not exclude the continued use of IS therapy with other groups of patients after cardiac surgery.

This finding of this study confirms the importance of the use of lung expansion therapies in the first three post CABG days to treat or prevent post-surgical atelectasis. The previous studies advised the use of lung expansion therapies such as IS and CPAP therapies in the first

three days after the surgery (Rezaiguia and Jayr, 1996; Zarbock, et al., 2009). The use of CPAP via mask therapy after CABG or major surgery is safe and no cardiac complications have been associated with its use. (Kindgen-Milles, Buhl, Loer & Muller, 2002; Zarbock, et al., 2009). The present study showed that there were no significant differences between the two study groups as regards the heart rate and the respiratory rate.

The duration of CPAP via mask therapy after patient extubation from mechanical ventilation ranges from 25 breaths to 10 hours in the previous studies (Stock, et al., 1984; Jousela, et al., 1994; Matte, et al., 2000; Denehy &Berney, 2001; Zarbock, et al., 2009). The present study suggested the use of half hour duration every two hours for the first three days after CABG. The effectiveness of CPAP via mask therapy usually disappears after several hours of use following patient extubation from mechanical ventilation. The key finding in this study was that CPAP via mask therapy was most effective when used for a short period (half hour) frequently (every two hours) for three days. Also, the present study used the set pressure of CPAP between four and six cmH_2O and found it to be effective in re-opening the collapsed alveoli (post-surgical atelectasis). This finding disagreed with another study (Zarbock, et al., 2009), that used high set pressure of CPAP level (between nine and ten cmH_2O). The patients usually do not tolerate this high level of CPAP pressure over a long period of time (Padovane & Cavenaghi, 2011).

The improvement in post-surgical atelectasis leads to an increase in patient mobilization, which is associated with a decrease in the length of hospital stay. The reduction of hospital stay will cause a decrease in the overall cost of cardiac surgery, which has been demonstrated in previous studies (Lawrence, et al., 1995; Ferguson, 1999; Brooks, et al., 2001). The present

study result showed a reduction in hospital stay of almost one day in CPAP every two hours group, and that reduction is equivalent to a reduction of approximately 54000 US dollars in the cost of cardiac surgery over a year. This was calculated according to the cost of cardiac surgery for 36 patients in the hospital where this study was conducted.

The goals of post-surgical atelectasis treatment are to re-open the collapsed alveoli and to remove the mucus or secretions from the lung airways. The patients were instructed in the first study to do huffing and coughing manoeuvre to expectorate mucus or secretion from the lung airways. However, the requirement of chest physiotherapy technique is one of the limitations for the first study due to this study compared the three groups as a single therapy.

The second study in this research project was developed from the first study because it used the best frequency of CPAP via mask therapy, and that is CPAP every two hours. Chest physiotherapy (CPT) technique was added to each group in this study and that means the second study compared the two groups as combined therapy. It compared CPAP via mask therapy every two hours and regular IS therapy, with added CPT therapy every four hours to both groups.

The finding of the second study showed a significant increase in the mean IC measured post therapy by more than half a litre (0.57 L) in CPAP via mask therapy for half an hour every two hours, with CPT therapy every four hours as compared to the measured IC baseline. This finding clearly confirmed the benefit of adding CPT therapy to CPAP via mask therapy for half an hour every two hours to improve post- surgical atelectasis. The increase of the mean IC post therapy in the equivalent group (CPAP for half an hour every two hours) of therapy

in the first study in this research was 4.6 L. This study finding agrees with a previous study (Borghi-Silva, et al., 2005), that found that adding CPT therapy to PEP therapy was better than PEP therapy alone in improving lung volume.

A previous study (Crowe and Bradley, 1997; Gosselink, et al., 2000) result showed no difference between adding IS therapy to chest physical therapy, and chest physical therapy alone, to treat post-surgical atelectasis. This present study result showed lower effectiveness of IS therapy with added CPT therapy as compared to CPAP every two hours group. This agrees with the findings of previous studies.

The effectiveness of added CPT therapy to CPAP therapy was because the present study used the complete technique of CPT therapy (such as chest percussion, vibrations, postural drainage and mobilization) and used CPT therapy every four hours. This finding agrees with the study by Borghi-Silva, *et al.*, (2005), which found that the use of complete CPT technique was more effective. However, the present study disagreed with another previous study (Westerdahl, et al., 2001) which used CPT therapy once or twice a day as a combined therapy to treat post-surgical atelectasis.

The second study used the CPT machine to perform the CPT techniques and found it more effective than the hand techniques. A previous study found that the use of hand technique was not effective (Crowe and Bradley, 1997; Gosselink, et al., 2000). However, the use of hand technique to perform CPT therapy is still better than not using it at all.

The second study in this research showed a reduction in hospital stay by one day in CPAP via mask therapy for half an hour every two hours with CPT therapy every four hours. However, there was no significant difference in the hospital stay and the reduction of cardiac surgery cost between the first and second studies in this research, as the reduction of hospital stay reduction was one day in both studies.

The second study showed that one participant died in both group within 30 days after the surgery, due to the development of other medical complications, such as renal or cardiac complications. These complications were not related to post-operative pulmonary complications or the use of CPAP via mask therapy. There was no difference in mortality rate between the first and second study in this research project because one participant died within 30 days after CABG in both studies and the reason of death was the development of other medical complications and not post-operative pulmonary complications. The result of both intervention studies in this research project showed the use of CPAP via mask therapy to treat or prevent post-surgical atelectasis after CABG is an effective and safe method.

In addition, the present research suggested several criteria to take into consideration when using CPAP via mask therapy to treat or prevent post-surgical atelectasis after cardiac surgery. The first criteria is that the CPAP via mask therapy should be performed by well-trained medical staff. The second criteria is that the CPAP therapy should be explained in detail to the patient before the surgery and the patient is advised to try it and get used to it. The third criteria is that the CPAP therapy should be applied by simple standalone CPAP machine with auto-leak feature to compensate for patient air leak. The fourth criteria is that

the type of mask used should be a soft and comfortable mask, either gel-mask or silicone-mask.

After the two intervention studies in this research project, the third study evaluated the patients' experience about CPAP therapy use via a questionnaire. To the best of my knowledge, this study is the first study done nationally, and probably also internationally, to evaluate post CABG patient's experience about the use of CPAP therapy. The third study evaluated the patients' compliance in two different frequencies of CPAP therapy (CPAP therapy every two hours and every four hours). The questionnaire evaluated the patient compliance, periodicity and side effects of CPAP via mask therapy.

The third study showed a high acceptance rate in most patients (93%) in CPAP every two hours group and in CPAP every four hours group (83%). This agrees with the previous studies (Pepin, et al., 1995; McArdle, et al., 1999), which found high compliance of CPAP therapy use. Other studies (Engleman, et al., 1999 & Weaver, et al., 2007), found a relationship between the frequency of CPAP therapy and the compliance rate. For example, an increase in the frequency of CPAP therapy use is usually associated with an increase in the compliance rate. This agrees with the finding of the third study, which showed the compliance rate for CPAP every two hours group to be higher than the compliance for CPAP every four hours group.

Also, this third study finding, showed high incidence (63%) of dry mouth and nose because there was no humidification system used in the CPAP machine. Heated or cold humidity would lead to a decrease in the side effects of dry nose or mouth during the CPAP use and

potentially better compliance. The use of humidification system with CPAP machine is very important to solve the problem of dry mouth and nose during the use of CPAP, and that is one of the limitations in this research project. However, drinking water after the therapy will usually decrease this type of problem. This agrees with previous studies (Massie, et al., 1999; Gay, et al., 2003; Kushida, et al., 2006), which found that the use of humidification system with CPAP therapy was very important to reduce the side effects of dry mouth and nose.

The third study showed that more than half of the participants complained about the mask being uncomfortable, in both groups, even with the use of the most comfortable gel face mask available in the market in this study. This may be due to participants tightening the mask around their faces, even though asked not to do so. The type of CPAP machine used in this study had auto-leak compensation which allowed to compensate for the small air leak around the mask, without affecting the CPAP pressure and this leads to increase in the comfort of using the mask as it does not need to be very tight. This study used face mask (it covers the nose and the mouth, also called oronasal mask) with CPAP therapy, because it is more effective and prevents leak if patient opens his or her mouth, which can lead to loosening and decrease in the CPAP pressure. This is common with nasal mask use. This agrees with a recent study (Fernandes, et al., 2012), which compared the use of nasal mask and face (oronasal) mask and found the face mask to be more effective. This study disagreed with another study (Mortimore, Whittle & Douglas, 1998), which recommended the use of nasal mask. For several reasons, the nasal mask increases the air leak by 50%, causes allergy to the face (Pepin, et al., 1995), and mouth leak, which is associated with lower compliance (Baltzan, et al., 2009).

Patients' experience with CPAP therapy was evaluated in the third study. The fourth study in this research project evaluated the medical staff (doctor, nurse and respiratory therapist) experience via a semi-structured interview. The type of lung expansion therapy (such as IS, CPAP, DBE, PEP, BiPAP) used was different in most of the hospitals that perform cardiac surgery procedures, all over the world. The medical staff's understanding of lung expansion therapies used is an important issue that leads to increased acceptance of the type of therapy used (Reeve, et al., 2007).

The fourth study in this research project evaluated the experience of different medical back ground staff (doctor, nurse and respiratory therapist) about CPAP therapy use. It evaluated the experience of all medical staff involved in the decision of using CPAP therapy. This makes it different from other studies (Tucker, et al., 1996; Overend, et al., 2010; Fiore, et al., 2010), which only evaluated the experience of individual medical staff, mostly the person applying the therapy like the physiotherapist. To the best of my knowledge, this fourth study is the first study of its kind, done nationally and internationally, as it evaluates the all the medical staff involved in the decision making of CPAP therapy after cardiac surgery.

This main finding of this fourth study showed high acceptance rate (86%) of the new method of CPAP via mask therapy to treat or prevent post- surgical atelectasis, and most of the participants agreed to continue using the new method in the future. Also, more than half of them (53%) preferred to use CPAP therapy every two hours, while the rest of them preferred to use it every four hours. This finding disagreed with another study (Westerdahl & Olsen, 2011) which suggested the use of DBE therapy as first choice to treat post-operative

pulmonary complications. Most of the participants in this present study suggested the use of CPAP via mask therapy as first choice.

In addition, this fourth study showed that 57% of the participants acknowledged the advantage of CPAP therapy to improve or prevent post-surgical atelectasis. This study supports the importance of post-surgical atelectasis as one of the most common post-operative pulmonary complication. The major disadvantage of using CPAP therapy in this study was gastric distension (36%). However, this problem can be solved by adjusting the flow rate and using the desired set of CPAP pressure.

After completing this research project about the alternative methods to treat or prevent post-surgical atelectasis after cardiac surgery, it is clear that there is benefit in this new method to treat or prevent post-surgical atelectasis. The new method, or CPAP via mask therapy, is a very important way of reducing or preventing post-operative pulmonary complications after cardiac surgery. This is particularly so in the sub-group of patients in this research, the smokers and the elderly patients. CABG procedures are frequently used in this sub-group of patient nowadays, for example, in the hospital where this research was conducted more than 90% of CABG procedures were performed on smokers.

8.2 Research limitation:

The importance and benefit of CPAP via mask therapy to treat or prevent post-surgical atelectasis is made clear in this research. However, this finding cannot be used as standard medical practice, due to the small group of patients in this research. A further clinical trial with a larges number of patients is required to confirm this finding.

Also, one of the side effects in this research relating to the CPAP therapy use is dry mouth or nose after the therapy, and that is because the CPAP machine used did not have a humidification system. The luck of availability of humidification system is one of the limitations in this research. It is recommended to use a humidification system with CPAP therapy to solve this problem.

Finally, the comfort of CPAP therapy mask is one of the most important factors leading to the acceptance of CPAP therapy by the patients. This research used the face gel mask which is the most comfortable mask available in the local market at the time this research was conducted. There is a new type of mask called full face mask and one of its features is that it is very comfortable for the patient. It is recommended to use it in the future to increase further the patient's compliance for CPAP therapy.

8.3 Research conclusion:

The use of CPAP via mask therapy for half an hour, every two hours, had better outcomes in treating or preventing post-surgical atelectasis after cardiac surgery, particularly in smokers and elderly patients. Adding chest physiotherapy to CPAP via mask therapy leads to even better outcomes. The keys factors for the successful use of CPAP therapy are the use of high technology CPAP device, a well-trained person to apply the device, the use of the most comfortable mask available, and apply over short period of time (half hour) with high frequency (every two hours). The use of CPAP therapy via mask had high acceptance rate by the participants and the medical staff. Future clinical trials should be conducted in large numbers of post CABG patients to confirm this finding.

8.4 Further research:

I am planning to conduct a national survey via a questionnaire to evaluate the present practice to treat or prevent post-operative pulmonary complications particularly post-surgical atelectasis after cardiac surgery in all Saudi cardiac centres.

REFERENCES:

Adams, W. L., McIlvain, H. E., Lacy, N. L., Magsi, H., Crabtree, B. F., Yenny, S. K. & Sitorius, M. A. (2002). Primary care for elderly people: why do doctors find it so hard? *The Gerontologist*, 42 (6), 835-842.

Agarwal, D. & Gupta, P. P. (2007). A comparison of peak expiratory flow measured from forced vital capacity and peak flow meter manoeuvres in healthy volunteers. *Annals of Thoracic Medicine*, 2 (3), 103-106.

Agostini, P. & Singh, S. (2009). Incentive spirometry following thoracic surgery: what should we be doing? *Physiotherapy*, 95 (2), 76-82.

Ahrens, T., Kollef, M., Stewart, J. & Shannon, W. (2004). Effect of kinetic therapy on pulmonary complications. *American Journal of Critical Care*, 13 (5), 376-383.

Akdur, H., Polat, M. G., Yigit, Z., Arabaci, U., Ozyilmaz, S. & Gurses, H. N. (2002). Effects of long intubation period on respiratory functions following open heart surgery. *Japanese Heart Journal*, 43 (5), 523-530.

AlHabib, K. F., Hersi, A., AlFaleh, H., Kurdi, M., Arafah, M., Youssef, M., AlNemer, K., Bakheet, A., AlQarni, A., Soomro, T., Taraben, A., Malik, A. & Ahmed, W. H. (2009). The Saudi Project for Assessment of Coronary Events (SPACE) registry: design and results of a phase I pilot study. *The Canadian Journal of Cardiology*, 25 (7), 255-258.

Almahmeed, W., Arnaout, M. S., Chettaoui, R., Ibrahim, M., Kurdi, M. I., Taher, M. A. & Mancia, G. (2012). Coronary artery disease in Africa and the Middle East. *Therapeutics and Clinical Risk Management*, 8, 65-72.

Almendros, I., Acerbi, I., Vilaseca, I., Montserrat, J. M., Navajas, D. & Farre, R. (2008). Continuous positive airway pressure (CPAP) induces early inflammation. *Sleep*, 31, 127–131.

Al-Nozha, M. M., Arafah, M. R., Al-Mazrou, Y. Y., Al-Maatouq, M. A., Khan, N. B., Khalil, M. Z., Al-Khadra, A. H., Al-Marzouki, K., Abdullah, M. A., Al-Harthi, S. S., Al-Shahid, M. S., Nouh, M. S. & Al-Mobeireek, A. (2004). Coronary artery disease in Saudi Arabia. *Saudi Medical Journal*, 25 (9), 1165-1171.

American Association for Respiratory Care (1993). Clinical practice guideline respiratory care. Use of positive airway pressure adjuncts to bronchial hygiene therapy. *Respiratory Care*, 38, 516-521.

American Association for Respiratory Care (AARC) (1991). Clinical Practice Guideline: Postural Drainage Therapy. *Respiratory Care*, 36 (12), 1418–1426.

American Association for Respiratory Care (AARC) (1993). Clinical Practice Guideline: Directed Cough. *Respiratory Care*, 38 (5), 495–499.

American Association for Respiratory Care (AARC) (1996). Clinical Practice Guideline: Spirometry update. *Respiratory Care*, 41 (7), 629–636.

American Thoracic Society (1995). Standardization of spirometry update. *American Journal of Respiratory and Critical Care Medicine*, 152 (3), 1107–1136.

Andrejaitiene, J., Sirvinskas, E. & Bolys, R. (2004). The influence of cardiopulmonary bypass on respiratory dysfunction in early postoperative period. *Medicina*, 40 (l), 7-12.

Arens, R., Gozal, D., Omlin, K. J., Vega, J., Boyd, K. P., Keens, T. G. & Woo, M. S. (1994). Comparison of high frequency chest compression and conventional chest physiotherapy in hospitalized patients with cystic fibrosis. *American Journal of Respiratory and Critical Care Medicine*, 150 (4), 1154-1157.

Arthur, H. M., Daniels, C., McKelvie, R., Hirsh, J. & Rush, B. (2000). Effect of a preoperative intervention on preoperative and postoperative outcomes in low-risk patients awaiting elective coronary artery bypass graft surgery. A randomized, controlled trial. *Annals of Internal Medicine*, 133 (4), 253-262.

Arunabh & Feinsilver, S. H. (2000). Respiratory monitoring. *Respiratory Care Clinics of North America*, 6 (4), 523-543.

Ashizawa, K., Hayashi, K., Aso, N. & Minami, K. (2001). Lobar atelectasis: diagnostic pitfalls on chest radiography. *The British Journal of Radiology*, 74 (877), 89-97.

Bakker, J., Campcell, A. & Neill, A. (2010). Randomized controlled trial comparing flexible and continuous positive airway pressure delivery: effects on compliance, objective and subjective sleepiness and vigilance. *Sleep*, 33 (4), 523-529.

Baltzan M. A., E lkholi O. & Wolkove N. (2009). Evidence of interrelated side effects with reduced compliance in patients treated with nasal continuous positive airway pressure. *Sleep Medicine*, 10 (2), 198-205.

Barbe, F., Mayoralas, L. R., Duran, J., Masa, J. F., Maimo, A., Montserrat, J. M., Monasterio, C., Bosch, M., Ladaria, A., Rubio, M., Rubio, R., Medinas, M., Hernandez, L., Vidal, S., Douglas, N. J. & Agusti, A. G. (2001). Treatment with continuous positive airway pressure is not effective in patients with sleep apnea but no daytime sleepiness. A randomized controlled trial. *Annals of Internal Medicine*, 134 (11), 1015-1023.

Bardi, G., Pierotello, R., Desideri, M., Valdisseri, L., Bottai, M. & Palla, A. (2000). Nasal ventilation in COPD exacerbations: early and late results of a prospective, controlled study. *The European Respiratory Journal*, 15, 98-104.

Barker, S. J. & Badal, J. J. (2008). The measurement of dyshemoglobins and total hemoglobin by pulse oximetry. *Current Opinion in Anaesthesiology*, 21 (6), 805-810.

Bastin, R., Moraine, J. J., Bardocsky, G., Kahn, R. J. & Melot, C. (1997). Incentive spirometry performance. A reliable indicator of pulmonary function in the early postoperative period after lobectomy? *Chest*, 111 (3), 559-563.

Batchelder, P. B. & Raley, D. M. (2007). Maximizing the laboratory setting for testing devices and understanding statistical output in pulse oximetry. *Anesthesia and Analgesia*, 105 (6), 85-94.

Baudouin, S. V. (2003). Lung injury after thoracotomy. *British Journal of Anaesthesia*, 91 (1), 132-142.

Beecroft, J., Zanon, S., Lukic, D. & Hanyl, P. (2003). Oral continuous positive airway pressure for sleep apnea: effectiveness, patient preference, and adherence. *Chest*, 124, 2200-2208.

Bellet, P. S., Kalinyak, K. A., Shukla, R., Gelfand, M. J. & Rucknagel, D. L. (1995). Incentive spirometry to prevent acute pulmonary complications in sickle cell diseases. *The New England Journal of Medicine*, 333 (11), 699-703.

Berney, S. & Denehy, L. (2002). A comparison of the effects of manual and ventilator hyperinflation on static lung compliance and sputum production in intubated and ventilated intensive care patients. *Physiotherapy Research International*, 7 (2), 100-108.

Bernstein, W. K. & Deshpande, S. (2008). Preoperative evaluation for thoracic surgery. *Seminars in Cardiothoracic and Vascular Anesthesia*, 12, 109-121.

Bigler, D. R. (2003). Lung function changes during anesthesia and thoracic surgery. *Ugeskrift for Laeger*, 165 (3), 232-235.

Bleakley, A. (2005). Stories as data, data as stories: making sense of narrative inquiry in clinical education. *Medical Education*, 39 (5), 534-540.

Borg, B. M. & Thompson, B. R. (2012). The measurement of lung volumes using body plethysmography: a comparison of methodologies. *Respiratory Care*, 57 (7), 1076-1083.

Borghi-Silva, A., Mendes, R., Costa, F., Di Lorenzo, V., Oliveira, C. & Luzzi, S. (2005).The influences of positive end expiratory pressure (PEEP) associated with physiotherapy intervention in phase I cardiac rehabilitation. *Clinics Journal*, 60 (6), 465-472.

Bosnak-Guclu, M., Gunduz, A. G., Nazliel, B. & Irkec, C. (2012). Comparison of functional exercise capacity, pulmonary function and respiratory muscle strength in patients with multiple sclerosis with different disability levels and healthy controls. *Journal of Rehabilitation Medicine*, 44 (1), 80-86.

Brasher, P. A., McClelland, K. H., Denehy, L. & Story, I. (2003). Does removal of deep breathing exercises from a physiotherapy program including pre-operative education and early mobilization after cardiac surgery alter patient outcomes? *The Australian Journal of Physiotherapy*, 49 (3), 165-173.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3 (2), 77-101.

Brazzale, D. J., Upward, A. L. & Pretto, J. J. (2010). Effects of changing reference values and definition of the normal range on interpretation of spirometry. *Respirology*, 15 (7), 1098-1103.

Brewer, L., Orr, J., Fulcher, E. & Markewitz, B. (2011). Evaluation of a CO_2 partial rebreathing functional residual capacity measurement method for use during mechanical ventilation. *Journal of Clinical Monitoring and Computing*, 25 (6), 397-404.

British Thoracic Society Standards of Care Committee (2002). Non-invasive ventilation in acute respiratory failure. *Thorax,* 57, 192–211.

Brochard, L., Mancebo, J., Wysocki, M., Lofaso, F., Conti, G., Rauss, A., et al. (1995). Non-invasive ventilation for acute exacerbations of chronic obstructive pulmonary disease. *The New England Journal of Medicine,* 333, 817–822.

Brooks, D., Crowe, J., Kelsey, C. J., Lacy, J. B., Parsons, J. & Solway, S. (2001). A clinical practice guideline on pre-operative cardiorespiratory physical therapy. *Physiotherapy Canada*, 53(1), 9-25.

Budak, Y. U., Huysal, K. & Polat, M. (2012). Use of a blood gas analyzer and a laboratory autoanalyzer in routine practice to measure electrolytes in intensive care unit patients. *BioMed Central Anesthesiology*, 2253, 12-17.

Budhiraja, R., Parthasarathy, S., Drake, C. L., Roth, T., Sharief, I., Budhiraja, P., Saunders, V. & Hudgel, D. W. (2007). Early CPAP use identifies subsequent adherence to CPAP therapy. *Sleep,* 30, 320-324.

Canet, J. & Mazo, V. (2010). Postoperative pulmonary complications. *Minerva Anestesiologica Journal*, 76 (2), 138-143.

Cavalheri, V., Camillo, C. A., Brunetto, A. F., Probst, V. S., Ramos, E. M. & Pitta, F. (2010). Effects of arm bracing posture on respiratory muscle strength and pulmonary function in patients with chronic obstructive pulmonary disease. *Portuguese Journal of Pulmonology*, 16 (6), 887-891.

Cavenaghi, S., Ferreira, L. L., Marino, L. H. & Lamari, N. M. (2011). Respiratory physiotherapy in the pre and postoperative myocardial revascularization surgery. *Brazilian Journal of Cardiovascular Surgery*, 26 (3), 455-461.

Celli, B., Rodriguez, K. & Snider, G. (1984). A controlled trial of intermittent positive pressure breathing, incentive spirometry, and deep breathing exercises in preventing pulmonary complications after abdominal surgery. *The American Review of Respiratory Disease Journal*, 130, 12-15.

Chai, C. L., Pathinathan, A. & Smith, B. (2006). Continuous positive airway pressure delivery interfaces for obstructive sleep apnoea. *The Cochrane Database of Systematic Reviews*, 18, (4), CD005308.

Chen, Y. C., Wu, L. F., Mu, P. F., Lin, L. H., Chou, S. S. & Shie, H. G. (2009). Using chest vibration nursing intervention to improve expectoration of airway secretions and prevent lung collapse in ventilated ICU patients: a randomized controlled trial. *Journal of the Chinese Medical Association*, 72 (6), 316-322.

Christensen, E. F., Schultz, P., Jensen, O. V., Egebo, K., Engberg, M., Gron, I. & Juhl B. (1991). Postoperative pulmonary complications and lung function in high-risk patients: a comparison of three physiotherapy regimens after upper abdominal surgery in general anesthesia. *Acta Anaesthesiologica Scandinavica*, 35 (2), 97-104.

Chumillas, S., Ponce, J. L., Delgado, F., Viciano, V. & Mateu, M. (1998). Prevention of postoperative pulmonary complications through respiratory rehabilitation: a controlled clinical study. *Archives of Physical Medicine and Rehabilitation*, 79 (1), 5-9.

Chuter, T. M., Weissman, C., Mathews, D. M. & Starker, P. M. (1990). Diaphragmatic breathing maneuvers and movement of the diaphragm after cholecystectomy. *Chest*, 97 (5), 1110–1114.

Claxton, B. A., Morgan, P., McKeague, H., Mulpur, A. & Berridge. J. (2003). Alveolar recruitment strategy improves arterial oxygenation after cardiopulmonary bypass. *Anaesthesia*, 58 (2), 111-116.

Clinkscale, D., Spihlman, K., Watts, P., Rosenbluth, D. & Kollef, M. H. (2012). A randomized trial of conventional chest physical therapy versus high frequency chest wall compressions in intubated and non-intubated adults. *Respiratory Care*, 57 (2), 221-228.

Covelli, H. D., Weled, B. J. & Beekman, J. F (1982). Efficacy of continuous positive airway pressure administered by face mask. *Chest*, 81 (2), 147-150.

Criee, C. P., Sorichter, S., Smith, H. J., Kardos, P., Merget, R., Heise, D., Berdel, D., Kohler, D., Magnussen, H., Marek, W., Mitfessel, H., Rasche, K., Rolke, M., Worth, H. & Jorres, R. A. (2011). Body plethysmography--its principles and clinical use. *Respiratory Medicine*, 105 (7), 959-971.

Criner, G., Barnette, R. & D'Alonzo, G. (2010). Critical Care Study Guide (2nd edition). Rehabilitation in the Intensive Care Unit. London. Springer New York Dordrecht Heidelberg.

Crowe, J. M & Bradley, C. A. (1997). The effectiveness of incentive spirometry with physical therapy for high-risk patients after coronary artery bypass surgery. *Physical Therapy*, 77 (3), 260-268.

Denehy, L., Carrol, S., Ntoumenopoulos, G. & Jenkins, S. (2001). A randomized controlled trial comparing periodic mask CPAP with physiotherapy after abdominal surgery. *Physiotherapy Research International Journal*, 6 (4), 236-250.

Dias, C. M., Vieira, Rde. O., Oliveira, J. F., Lopes, A. J., Menezes, S. L. & Guimaraes F. S. (2011). Three physiotherapy protocols: effects on pulmonary volumes after cardiac surgery. *Respiratory Tract Diseases Journal*, 37 (1), 54-60.

Doyle, R. L. (1999). Assessing and modifying the risk of postoperative pulmonary complications. *Chest*, 115 (5), 77-81.

Dressel, H., Filser, L., Fischer, R., de la Motte, D., Steinhaeusser, W., Huber, R. M., Nowak, D. & Jorres R. A. (2012). Lung diffusing capacity for nitric oxide and carbon monoxide: dependence on breath-hold time. *Chest*, 133 (5), 1149-1154.

Dronkers, J., Veldman, A., Hoberg, E., Waal, C. & Meeteren, N. (2008). Prevention of pulmonary complications after upper abdominal surgery by preoperative intensive inspiratory muscle training: a randomized controlled pilot study. *Clinical Rehabilitation*, 22 (2), 134-142.

Dueck, R. (2006). Alveolar recruitment versus hyperinflation: A balancing act. *Current Opinion in Anaesthesiology,* 19 (6), 650-654.

Duggan, M. & Kavanagh, B. P. (2010). Perioperative modifications of respiratory function. Best Practice & Research. *Clinical Anaesthesiology*, 24 (2), 145-155.

Dureuil, B. (2002). Management of COPD patients undergoing surgery. In: Simlowski T, Whitelaw WA, Derenne JP, editors. *Clinical management of chronic obstructive pulmonary disease*. New York: Marcel Dekker.

Ebeo, C. T., Benotti, P. N., Byrd, R. P., Elmaghraby, Z. & Lui, J. (2002). The effect of bi-level positive airway pressure on postoperative pulmonary function following gastric surgery for obesity. *Respiratory Medicine*, 96 (6), 672-676.

Eisner, M. D., Iribarren, C., Yelin, E. H., Sidney, S., Katz, P. P., Ackerson, L., Lathon, P., Tolstykh, I., Omachi, T., Byl, N. & Blanc, P. D. (2008). Pulmonary function and the risk of functional limitation in chronic obstructive pulmonary disease. *American Journal of Epidemiology,* 167 (9), 1090-1101.

Engleman, H. M. & Wild, M. R. (2003). Improving CPAP use by patients with the sleep apnoea/hypopnoea syndrome (SAHS). *Sleep Medicine Reviews,* 7, 81-99.

Engleman, H. M., Kingshott, R. N., Wraith, P. K., Mackay, T. W., Deary, I. J. & Douglas, N. J. (1999). Randomized placebo-controlled crossover trial of continuous positive airway pressure for mild sleep Apnea/Hypopnea syndrome. *American Journal of Respiratory and Critical Care Medicine*, 159 (2), 461-467.

Epstein, S. K. (2005). Anatomy and physiology of tracheostomy. *Respiratory Care*, 50 (4), 476-482.

Fabienne, M., Benoit, B., Bruno, G., Abdesslam, C., Erwan, L., Marie-France, H. & Jacques, B. (2007). Continuous Positive Airway Pressure versus Bilevel Noninvasive in acute cardiogenic pulmonary edema: a randomized multicenter trial. *Annals of Emergency Medicine Journal*, 50, 666-675.

Faul, F., Erdfelder, E., Lang, A. G. & Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods*, 39 (2), 175-191.

Faul, F., Erdfelder, E., Buchner, A. & Lang A. G. (2009). Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behavior research methods*, 41 (4), 1149-1160.

Ferguson, M. K. (1999). Preoperative assessment of pulmonary risk. *Chest*, 115 (5), 58-63.

Fernandez, R., Cabera, C., Rubinos, G., Pando, A., Galindo, R., Rodriguez, F., Lopez, F., Gonzalez, I. & Casan, P. (2012). Nasal versus Oronasal mask in home mechanical ventilation: the preference of patients as a strategy for choosing the interface. *Respiratory Care*, 57 (9), 1413-1417.

Ferreyra, G., Long, Y. & Ranieri, V. M. (2009). Respiratory complications after major surgery. *Current Opinion in Critical Care*, 15(4), 342-348.

Fink, J. B. (2002). Positioning versus postural drainage. *Respiratory Care*, 47 (7), 769-777.

Fiore, J. F., Chiavegato, L. D., Paisani, D. M. & Colucci, D. B. (2010). Utilization of positive-pressure devices for breathing exercises in the hospital setting: a regional survey in Sao Paulo, Brazil. *Respiratory Care*, 55 (6), 719-724.

Flaminiano, L. E & Celli, B. R. (2001). Respiratory muscle testing. *Clinics in Chest Medicine*, 22 (4), 661-677.

Flesch, J. D. & Dine, C. J. (2012). Lung volumes: measurement, clinical use, and coding. *Chest*, 142 (2), 506-510.

Ford, E. S., Ajani, U. A., Croft, J. B., Critchley, J. A., Labarthe, D. R., Kottke, T. E., Giles, W. H. & Capewell, S. (2007). Explaining the decrease in U.S. deaths from coronary disease, 1980-2000. *The New England Journal of Medicine*, 356 (23), 2388-2398.

Forti, E., Ike, D., Barbalho-Moulim, M., Rasera, I. & Costa, D. (2009). Effects of chest physiotherapy on the respiratory function of postoperative gastroplasty patients. *Clinics*, 64 (7), 683-689.

Freitas, E., Soares, B., Cardoso, J. & Atallah, A. (2007). Incentive spirometry for preventing pulmonary complication after coronary artery bypass graft. *The Cochrane Database Systemic Reviews*, (3) CD 4466.

Gale, G. D. & Sanders, D. E. (1980). Incentive spirometry: its value after cardiac surgery. *Canadian Anaesthetists' Society Journal*, 27 (5), 475-480.

Ganguly, K. C., Hiron, M. M., Mridha, Z. U., Biswas, M., Hassan, M. K., Saha, S. C. & Rahman, M. M. (2008). Comparison of sputum induction with broncho-alveolar lavage in the diagnosis of smear-negative pulmonary tuberculosis. *Mymensingh Medical Journal*, 17 (2), 115-123.

Gay, P. C., Herold, D. L. & Olson, E. J. (2003). A randomized, double-blind clinical trial comparing continuous positive airway pressure with a novel bilevel pressure system for treatment of obstructive sleep apnea syndrome. *Sleep*, 26, 864-869.

Gay, P., Weaver, T., Loube, D. & Iber, C. (2006). Evaluation of positive airway pressure treatment for sleep related breathing disorders in adult. *Sleep*, 29 (3), 381-401.

Gerrish, K. & Lacey, A. (2010). The research process. *The Research Process in Nursing*, (6th edition). Oxford, Blackwell.

Gilbert, N. (2008). Qualitative Interviewing. *Researching Social Life* (3rd edition). London, SAGE Publications Ltd.

Gosselink, R., Bott, J., Johnson, M., Dean, E., Nava, S., Norrenberg, M., Schönhofer, B., Stiller, K., van de Leur, H. & Vincent, J. L. (2008). Physiotherapy for adult patients with critical illness: recommendations of the European Respiratory Society and European Society of Intensive Care Medicine Task Force on Physiotherapy for Critically Ill Patients. *Intensive Care Medicine*, 34 (7), 1188-1199.

Gottlieb, A. & Sliver, M. (2001). Atherosclerosis: pathology and pathogenesis. *Cardiac Pathology*. M. Reinwald. Philadelphia, Churchill Livingstone.

Groeben, H. (2006). Epidural anesthesia and pulmonary function. *Journal of Anesthesia*, 20 (4), 290-299.

Gruber, E. M. & Tschernko, E. M. (2003). Anaesthesia and postoperative analgesia in older patients with chronic obstructive pulmonary disease: special considerations. *Drugs & Aging*, 20 (5), 347-360.

Guimaraes, M. M., El Dib, R., Smith, A. F. & Matos, D. (2009). Incentive spirometry for prevention of postoperative pulmonary complications in upper abdominal surgery. *The Cochrane Database of Systematic Reviews*, 8 (3), CD006058.

Guindon DE, Boisclair G. World Health Organization Tobacco Free Initiative. Past, Current and Future Trends in Tobacco use. (2003). [Accessed February 3, 2013]. (HNP discussion paper series; economics of tobacco control paper 6). Available from: http://siteresources.worldbank.org/HEALTHNUTRITIONANDPOPULATION/Resources/281627-1095698140167/Guindon-PastCurrent-whole.pdf.

Haeffener, M. P., Ferreira, G. M., Barreto, S. S., Arena, R. & Dall'Ago, P. (2008). Incentive spirometry with expiratory positive airway pressure reduces pulmonary complications, improves pulmonary function and 6-minute walk distance in patients undergoing coronary artery bypass graft surgery. *American Heart Journal*, 156 (5), 900.

Hakim, I. A., Alsaif, M. A., Alduwaihy, M., Al-Rubeaan, K., Al-Nuaim, A. R. & Al-Attas, O. S. (2003). Tea consumption and the prevalence of coronary heart disease in Saudi adults: results from a Saudi national study. *Preventive Medicine*, 36 (1), 64-70.

Hall, J. C., Tarala, R. A., Tapper, J. & Hall, J. L. (1996). Prevention of respiratory complications after abdominal surgery: a randomised clinical trial. *British Medical Journal*, 312 (7024), 148-152.

Hall, J. C., Tarala, R., Harris, J., Tapper, J. & Christiansen, K. (1991). Incentive spirometry versus routine chest physiotherapy for prevention of pulmonary complications after abdominal surgery. *Lancet*, 337 (8747), 953-956.

Hansdottir, V., Philip, J., Olsen, M. F., Eduard, C., Houltz, E. & Ricksten S. E. (2006). Thoracic epidural versus intravenous patient-controlled analgesia after cardiac surgery: a randomized controlled trial on length of hospital stay and patient-perceived quality of recovery. *Anesthesiology*, 104 (1), 142-151.

Hedenstierna, G. & Rothen, H.U. (2000). Atelectasis formation during anesthesia: causes and measures to prevent it. *Journal of Clinical Monitoring and Computing*, 16 (5-6), 329-335.

Hedenstierna, G. & Sandhagen, B. (2006). Assessing dead space. A meaningful variable? *Minerva Anestesiologica*, 72 (6), 521-528.

Heinze, H. & Eichler, W. (2009). Measurements of functional residual capacity during intensive care treatment: the technical aspects and its possible clinical applications. *Acta Anaesthesiologica Scandinavica*, 53 (9), 1121-1130.

Herdy, A. H., Marcchi, P. L., Vila, A., Tavares, C., Collaco, J., Niebauer, J. & Ribeiro J. P. (2008). Pre- and postoperative cardiopulmonary rehabilitation in hospitalized patients undergoing coronary artery bypass surgery: a randomized controlled trial. *American Journal of Physical Medicine and Rehabilitation*, 87 (9), 714-719.

Hill, K., Patman, S. & Brooks, D. (2010). Effect of airway clearance techniques in patients experiencing an acute exacerbation of chronic obstructive pulmonary disease: a systematic review. *Chronic Respiratory Disease*, 7 (1), 9-17.

Hoffman, S. N., TenBrook, J. A., Wolf, M. P., Pauker, S. G., Salem, D. N. &Wong, J. B. (2003). A meta-analysis of randomized controlled trials comparing coronary artery bypass graft with percutaneous transluminal coronary angioplasty: one- to eight-year outcomes. *Journal of the American College of Cardiology*, 41(8):1293-1304.

Hollandt, J. H. & Mahlerwein, M. (2003). Nasal breathing and continuous positive airway pressure (CPAP) in patients with obstructive sleep apnea (OSA). *Sleep and Breath*, 7 (2), 87-94.

Howard, L. & Ashley, C. (2003). Nutrition in the perioperative patient. *Annual Review of Nutrition*, 23, 263-82.

Hristara-Papadopoulou, A., Tsanakas, J., Diomou, G. & Papadopoulou, O. (2008). Current devices of respiratory physiotherapy. *Hippokratia*, 12 (4), 211-220.

Hughes, J. M. & Pride, N. B. (2012). Examination of the carbon monoxide diffusing capacity (DL(CO)) in relation to its KCO and VA components. *American Journal of Respiratory and Critical Care Medicine*, 186 (2), 132-139.

Hulzebos, E. H., Helders, P. J., Favie, N. J., De Bie, R. A., Brutel de la Riviere, A. & Van Meeteren, N. L. (2006). Preoperative intensive inspiratory muscle training to prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery: a randomized clinical trial. *Journal of the American Medical Association*, 296 (15), 1851-1857.

Imberger, G., Mcllroy, D., Pace, N. L., Wetterslev, J., Brok, J. & Moller, A. M. (2010). Positive end-expiratory pressure (PEEP) during anaesthesia for the prevention of mortality and postoperative pulmonary complications. *The Cochrane Database Systemic Reviews*, 8 (9), CD007922.

Iverson, L. I., Ecker, R. R., Fox, H. E. & May, I. A. (1978). A comparative study of IPPB, the incentive spirometer, and blow bottles: the prevention of atelectasis following cardiac surgery. *The Annals of Thoracic Surgery*, 25 (3), 197-200.

Jenkins, S. C., Soutar, S. A., Loukota, J. M., Johnson, L. C. & Moxham, J. (1989). Physiotherapy after coronary artery surgery: are breathing exercises necessary? *Thorax*, 44 (8), 634–639.

Jensen, L. & Yang, L. (2007). Risk factors for postoperative pulmonary complications in coronary artery bypass graft surgery patients. *European Journal of Cardiovascular Nursing*, 6 (3), 241-246.

Jensen, L. A., Onyskiw, J. E. & Prasad, N. G. (1999). Meta-analysis of arterial oxygen saturation monitoring by pulse oximetry in adults. *Heart Lung*, 27 (6), 387-408.

Johnson J. (2002). In-depth interviewing. In: Gubrium J, Holstein J, eds. *Handbook of Qualitative Research*. California, Thousand Oaks, Sage.

Johnson, D. C. (2000). Importance of adjusting carbon monoxide diffusing capacity (DLCO) and carbon monoxide transfer coefficient (KCO) for alveolar volume. *Respiratory Medicine*, 94 (1), 28-37.

Johnson, D., Hurst, T., Thomson, D., Mycyk, T., Burbridge, B. & et al. (1996). Respiratory function after cardiac surgery. *Journal of Cardiothoracic and Vascular aAesthesia*, 10, 571-577.

Joo, M. J. & Herdegen, J. J. (2007). Sleep apnea in an urban public hospital: assessment of severity and treatment adherence. *Journal of Clinical Sleep Medicine*, 3, 285-288.

Jousela, I., Rasanen, J., Verkkala, K., Lamminen, A., Makelainen, A. & Nikki, P. (1994). Continuous positive airway pressure by mask in patients after coronary surgery. *Acta Anaesthesiologica Scandinavica*, 38 (4), 311-316.

Kakkar, R. K. & Berry, R. B. (2007). Positive airway pressure treatment for obstructive sleep apnea. *Chest*, 132 (3), 1057-1072.

Kalan, A., Kenyon, G. S., Seemungal, T. A. & Wedzicha, J. A. (1999). Aderse effects of nasal continuous positive airway pressure therapy in sleep apnoea syndrome. *The Journal of Laryngoloy and Otology*, 113 (10), 888-892.

Kallet, R. H. & Diaz, J. V. (2009). The physiologic effects of noninvasive ventilation. *Respiratory Care*, 54, 102-115.

Kanat, F., Golcuk, A., Teke, T. & Golcuk, M. (2007). Risk factors for postoperative pulmonary complications in upper abdominal surgery. *Australian and New Zealand Journal of Surgery*, 77 (3), 135-141.

Kelleher, J. F. (1989). Pulse oximetry. *Journal of Clinical Monitoring*, 5 (1), 37-62.

Kempainen, R. R. & Benditt, J. O. (2001). Evaluation and management of patients with pulmonary disease before thoracic and cardiovascular surgery. *Seminars in Thoracic and Cardiovascular Surgery*, 13(2):105-115.

Kindgen-Milles, D., Buhl, R., Loer, S. A. & Muller E. (2002). Nasal CPAP therapy: effects of different CPAP levels on pressure transmission into the trachea and pulmonary oxygen transfer. *Acta Anaesthesiologica Scandinavica*, 46 (7), 860-865.

Kips, J. C. (1997). Preoperative pulmonary evaluation. *Acta Clinica Belgica*, 52 (5), 301-305.

Kramer, N., Meyer, T. J., Meharg, J., Cece, R. D. & Hill, N. S. (1995). Randomized prospective trial of noninvasive positive pressure ventilation in acute respiratory failure. *American Journal of Respiratory and Critical Care Medicine*, 151, 1799–1806.

Kryger, M. H. (2005). Management of obstructive sleep apnoea: *Review in Principle and Practice of Sleep Medicine*, (5th Edition). Philadelphia, Saunders.

Kushida, C. A., Littner, M. R., Hirshkowitz, M., Morgenthaler, T. I., Alessi, C. A., Baily, D., Boehlecke, B., Brown, T. M., Coleman, J., Friedman, L. & et al. (2006). Practice parameters for the use of continuous and bilevel positive airway pressure devices to treat adult patients with sleep-related breathing disorders. *Sleep*, 29, 375-380.

Langenderfer, B. (1998). Alternatives to percussion and postural drainage. A review of mucus clearance therapies: percussion and postural drainage, autogenic drainage, positive expiratory pressure, flutter valve, intrapulmonary percussive ventilation and high-frequency chest compression with the ThAIRapy Vest. *Journal of Cardiopulmonary Rehabilitation*, 18, 283-289.

Larsen, K. R., Ingwersen, U., Bertelsen, M. T., Kiil-Nielsen, K., Laub, M. S., Bach, K. S., Hansen, K. H. & Sandermann, J. (1994). Prevention of postoperative pulmonary complications after heart-lung surgery. Comparison of 3 different mask physiotherapy regimens. *Ugeskrift for Laeger*, 156 (39), 5689-5692.

Lawrence, V. A., Hilsenbeck, S. G., Mulrow, C. D., Dhanbla, R, Sapp, J. & Page, C.P. (1995). Incidence and hospital stay for cardiac and pulmonary complications after abdominal surgery. *Journal of General Internal Medicine*, 10 (12), 671-678.

Lawrence, V., Cornell, J. & Semtana, G. (2006). Strategies to reduce postoperative pulmonary complications after noncardiothoraic surgery: systemic review for the American college of physicians. *Annals of Internal Medicine Journal*, 144 (8), 596-608.

Lederer, D. H., Vandewater, J. M. & Indech, R. B. (1980). Which breathing device should the preoperative patient use? *Chest*, 77, 610-613.

Lee, W. W., Mayberry, K., Crapo, R. & Jensen R. L. (2000). The accuracy of pulse oximetry in the emergency department. *The American Journal of Emergency Medicine*, 18 (4), 427-431.

Lenique, F., Habis, M., Lofaso, F., Dubois-Rande, J. L., Harf, A. & Brochard, L. (1997). Ventilatory and hemodynamic effects of continuous positive airway pressure in left heart failure. *American Journal of Respiratory and Critical Care Medicine*, 155 (2), 500-505.

Lim, W. S., Carty, S. M., Macfarlane, J. T., Anthony, R. E., Christian, J., Dakin, K. S. & Dennis, P. M. (2002). Respiratory rate measurement in adults--how reliable is it? *Respiratory Medicine*, 96 (1), 31-33.

Lindner, K. H., Lotz, P. & Ahnefeld, F. W. (1987). Continuous positive airway pressure effect on functional residual capacity, vital capacity and its subdivisions. *Chest*, 92 (1), 66-70.

Mack, M. J., Brown, P. P., Kugelmass, A. D., Battaglia, S. L., Tarkington, L. G., Simon, A. W., Culler, S. D. & Becker, E. R. (2004). Current status and outcomes of coronary revascularization 1999 to 2002: 148,396 surgical and percutaneous procedures. *The Annals of Thoracic Surgery*, 77 (3), 761-766.

Magnusson, L., Zemgulis, V., Wicky, S., Tyden, H. & Hedenstierna, G. (1998). Effect of CPAP during cardiopulmonary bypass on postoperative lung function. An experimental study. *Acta Anaesthesiologica Scandinavica*, 42 (10), 1133-1138.

Mang, H. & Obermayer, A. (1989). Imposed work of breathing during sustained maximal inspiration: comparison of six incentive spirometers. *Respiratory Care*, 34, 1122-1128.

Manoharan, S. C. & Swaminathan, R. (2009). Prediction of forced expiratory volume in normal and restrictive respiratory functions using spirometry and self-organizing map. *Journal of Medical Engineering and Technology*, 33 (7), 538-543.

Massie, C. A., Hart, R. W., Peralez, K. & Richards, G. N. (1999). Effects of humidification on nasal symptoms and compliance in sleep apnea patients using continuous positive airway pressure. *Chest*, 116 (2), 403-408.

Matsuo, K. & Palmer, J. B. (2008). Anatomy and physiology of feeding and swallowing: normal and abnormal. *Physical Medicine and Rehabilitation Clinics of North America*, 19 (4), 691-707.

Matte, P., Jacquet, L., Van Dyck, V. & Goenen, M. (2000). Effects of conventional physiotherapy, continuous positive airway pressure and non-invasive ventilatory support with bilevel positive airway pressure after coronary artery bypass grafting. *Acta Anaesthesiologica Scandinavica*, 44 (1), 75–81.

McArdle, N., Devereux, G., Heidarnejad , H., Engleman, H. M., Mackay, T. W. & Douglas, N. J. (1999). Long-term use of CPAP therapy for sleep apnea/hypopnea syndrome. *American Journal of Respiratory and Critical Care Medicine*, 159, 1108-1114.

McEvoy, R. D. & Thornton, A. T. (1984), Treatment of obstructive sleep apnea syndrome with nasal continuous positive airway pressure. *Sleep*, 7, 313-325.

McIlwaine, M. (2007). Chest physical therapy, breathing techniques and exercise in children with CF. Paediatric Respiratory Reviews, 8 (1), 8-16.

Means, M. K., Edinger, J. D. & Husain, A. M. (2004). CPAP compliance in sleep apnea patients with and without laboratory CPAP titration. *Sleep and Breath*, 8, 7-14.

Mehta, S. & Hill, N. (2001). Noninvasive ventilation. *American Journal of Respiratory and Critical Care Medicine*, 163, 540-577.

Meyers, J. R., Lembeck, L., O'Kane, H. & Baue, A. E. (1975). Changes in functional residual capacity of the lung after operation. *Archives of Surgery*, 110 (5), 576-583.

Miller W. (1992). Routine, ceremony or drama: an exploratory field study of the primary care clinical encounter. *The Journal of Family Practice*, 34 (3), 289–296.

Minschaert, M., Vincent, J. L., Ros, A. M. & Kahn, R. J. (1982). Influence of incentive spirometry on pulmonary volumes after laparotomy. *Acta Anaesthesiologica Belgica*, 33 (3), 203-209.

Montserrat, J. M., Ferrer ,M., Hernandez, L., Farre, R., Vilagut, G., Navajas, D., Badia, J. R., Carrasco, E., De Pablo, J. & Ballester, E. (2001). Effectiveness of CPAP treatment in daytime function in sleep apnea syndrome: a randomized controlled study with an optimized placebo. *American Journal of Respiratory and Critical Care Medicine*, 164(4), 608-613.

Moreno, A. M., Castro, R. R., Sorares, P. P., Sant' Anna, M., Cravo, S. L. & Nóbrega, A. C. (2011). Longitudinal evaluation the pulmonary function of the pre and postoperative periods in the coronary artery bypass graft surgery of patients treated with a physiotherapy protocol. *Journal of Cardiothoracic Surgery*, 6, 62.

Moritz, F., Brousse, B., Gellee, B., Chajara, A., LHer, E., Hellot, M. F. & Benichou, J. (2007). Continuous Positive Airway Pressure versus Bilevel Noninvasive in acute cardiogenic pulmonary edema: a randomized multicenter trial. *Annals of Emergency Medicine Journal*, 50, 666-675.

Morris, B. A., Benetti, M., Marro, H. & Rosenthal, C. K. (2010). Clinical practice guidelines for early mobilization hours after surgery. *Orthopaedic nursing*, 29 (5), 290-316.

Mortimore, I. L., Whittle, A. T. & Douglas, N. J. (1998). Comparison of nose and face mask CPAP therapy for sleep apnoea. *Thorax*, 53 (4), 290-292.

Muller, A. P., Olandoski, M., Macedo, R., Costantini, C. & Guarita-Souza, L. C. (2006). Comparative study between intermittent (Muller Reanimator) and continuous positive airway pressure in the postoperative period of coronary artery bypass grafting. *Arquivos Brasileiros de Cardiologia*, 86 (3), 232-239.

Murphy, G. S., Szokol, J. W., Curran, R. D., Votapka, T. V. & Vender, J. S. (2001). Influence of a vital capacity maneuver on pulmonary gas exchange after cardiopulmonary bypass. *Journal of Cardiothoracic and Vascular Anesthesia*, 15 (3), 336-340.

Myrianthefs, P. & Batistaki, C. (2007). Preoperative pulmonary evaluation in patients scheduled for lung operations. *Journal of Balkan Union of Oncology*, 12 (2), 163-171.

Nakata, S., Noda, A., Yagi, H., Yanagi, E., Mimura, T., Okada, T., Misawa, H. & Nakashima, T. (2005). Nasal resistance for determinant factor of nasal surgery in CPAP failure patients with obstructive sleep apnea syndrome. *Rhinology*, 43, 296-299.

Naunheim, K. S., Wood, D. E., Krasna, M. J., DeCamp, M. M., Ginsburg, M. E., McKenna, R. J., Criner, G. J., Hoffman, E. A., Sternberg, A. L. & Deschamps, C. (2006). Predictors of operative mortality and cardiopulmonary morbidity in the National Emphysema Treatment Trial. *The Journal of Thoracic and Cardiovascular Surgery*, 131, 43–53.

Nijland, R., Jongsma, H. W., Nijhuis, J. G., Oeseburg, B. & Zijlstra, W. G. (1995). Notes on the apparent discordance of pulse oximetry and multi-wavelength haemoglobin photometry. *Acta Anaesthesiologica Scandinavica*, 107, 49-52.

Nolan, G. M., Ryan, S., Oconnor, T. M. & McNicholas, W. T. (2006). Comparison of three auto-adjusting positive pressure devices in patients with sleep apnoea. *The European Respiratory Journal*, 28 (1), 159-64.

Noordzij, J. P. & Ossoff, R. H. (2006). Anatomy and physiology of the larynx. *Otolaryngologic Clinics of North America*, 39 (1), 1-10.

Northrup, W. F., Emery, R. W., Nicoloff, D. M., Lillehei, T. J., Holter, A. R. & Blake, D. P. (2004). Opposite trends in coronary artery and valve surgery in a large multisurgeon practice, 1979-1999. *The Annals of Thoracic Surgery*, 77 (2), 488-495.

O'Donohue, W. J. (1992). Postoperative pulmonary complications. When are preventive and therapeutic measures necessary? *Postgraduate Medicine*, 91(3), 167-168.

Overend, T. J., Anderson, C. M., Jackson, J., Lucy, S. D., Prendergast, M. & Sinclair, S. (2010). Physical therapy management for adult patients undergoing cardiac surgery: a canadian practice survey. *Physiotherapy Canada*, 62 (3), 215-221.

Overend, T., Anderson, C., Lucy, S., Bhatia, C., Jonsson, B. & Timmermans, C. (2001). The effect of incentive spirometry on postoperative pulmonary complications: a systematic review. *Chest*, 120 (3), 971–978.

Padmanabhan, U., Leslie, K., Eer, A. S., Maruff, P. & Silbert, B. S. (2009). Early cognitive impairment after sedation for colonoscopy: the effect of adding midazolam and/or fentanyl to propofol. *Anesthesia and Analgesia*, 109 (5), 1448-1455.

Padovani, C. & Cavenaghi, O. M. (2011). Alveolar recruitment in patients in the immediate postoperative period of cardiac surgery. Brazilian Journal of Cardiovascular Surgery, 26 (1), 116-121.

Palmerini, T., Biondi-Zoccai, G., Reggiani, L. B., Sangiorgi, D., Alessi, L., De Servi, S., Branzi, A. & Stone, G. W. (2012). Risk of stroke with coronary artery bypass graft surgery compared with percutaneous coronary intervention. *Journal of the American College of Cardiology*, 60 (9), 798-805.

Pappalardo, F., Franco, A., Landoni, G., Cardano, P., Zangrillo, A. & Alfieri, O. (2004). Long-term outcome and quality of life of patients requiring prolonged mechanical ventilation after cardiac surgery. *European Journal of Cardiothoracic Surgery*, 25 (4), 548-52.

Pasquina, P., Merlani, P., Granier, J. M. & Ricou, B. (2004). Continuous positive airway pressure versus noninvasive pressure support ventilation to treat atelectasis after cardiac surgery. *Anesthesia and Analgesia*, 99 (4), 1001-1008.

Pasquina, P., Tramer, M. R., Granier, J. M. & Walder, B. (2006). Respiratory physiotherapy to prevent pulmonary complication after abdominal surgery: a systematic review. *Chest*, 130 (6), 1887-1899.

Pasquina, P., Tramers, M. R. & Walder, B. (2003). Prophylactic respiratory physiotherapy after cardiac surgery: systematic review. *British Medical Journal*, 327 (7428), 1379–1381.

Paul, W. L. & Downs, J. B. (1981). Postoperative atelectasis: Intermittent positive pressure breathing, incentive spirometry, and face-mask positive end-expiratory pressure. *Archives of Surgery*, 116 (7), 861-863.

Pedersen, T. (1994): Complications and death following anaesthesia. A prospective study with special reference to the influence of patient, anaesthesia, and surgery related risk factors. *Danish Medical Bulletin*, 41(3), 319-331.

Pedersen, T., Moller, A. M. & Hovhannisyan, K. (2009). Pulse oximetry for perioperative monitoring. *The Cochrane Database of Systematic Reviews*, (4), CD002013.

Pepin, J. L., Leger, P., Veale, D., Langevin, B., Robert, D. & Levy, P. (1995). Side effects of nasal contiuous positive airway pressure in sleep apnea syndrome. Study of 193 patients in two French sleep centers. *Chest*, 107 (2), 375-381.

Petty, T. L. & Doherty, D. E. (2004). The National Lung Health Education Program: roots, mission, future directions. *Respiratory Care*, 29(6), 678–683.

Petz, T. J. (1979). Physiologic effects of IPPB, blow bottles and incentive spirometry. *Current Review for Respiratory Therapy*, 1, 107-111.

Pfenninger, J. & Roth, F. (1977). Intermittent positive pressure breathing (IPPB) versus incentive spirometer (IS) therapy in the postoperative period. *Intensive Care Medicine*, 3 (4), 279-81.

Pierson, D. J. (1997). Noninvasive positive pressure ventilation: history and terminology. *Respiratory Care*, 42, 370-378.

Pinheiro, A. C., Novais, M. C., Neto, M. G., Rodrigues, M. V., de Souza Rodrigues, E., Aras, R. & Carvalho, V. O. (2011). Estimation of lung vital capacity before and after coronary artery bypass grafting surgery: a comparison of incentive spirometer and ventilometry. *Journal of Cardiothoracic Surgery*, 6, 70.

Pitta, F., Takaki, M. Y., Oliveira, N. H., Santanna, T. J., Fontana, A. D., Kovelis, D., Camillo, C. A., Probst, V. S. & Brunetto, A. F. (2008). Relationship between pulmonary function and physical activity in daily life in patients with COPD. *Respiratory Medicine*, 102 (8), 1203-1207.

Placidi, G., Cornacchia, M., Polese, G., Zanolla, L., Assael, B. & Braggion, C. (2006). Chest physiotherapy with positive airway pressure: a pilot study of short-term effects on sputum clearance in patients with cystic fibrosis and severe airway obstruction. *Respiratory Care Journal*, 51, 1145-1153.

Pretre, R. & Turina, M. I. (2001). Choice of revascularization strategy for patients with coronary artery disease. *Journal of the American Medical Association*, 285 (8), 992-994.

Pryor, J. A., Webber, B. A., Bethune, D. D., Potter, H. & Mckenzie, D. (2008). *Physiotherapy techniques* (2nd edition). London, Churchill Livingstone.

Qaseem, A., Snow, V., Fitterman, N., Hornbake, E. R., Lawrence, V. A., Smetana, G. W., Weiss, K., Owens, D. K., Aronson, M., Barry, P., Casey, D. E., Cross, J. T., Fitterman, N., Sherif, K. D. & Weiss, K. B. (2006). Risk assessment for and strategies to reduce perioperative pulmonary complications for patients undergoing noncardiothoracic surgery: a guideline from the American College of Physicians. *Annals of Internal Medicine*, 144(8), 575-580.

Raoof, S., Chowdhrey, N., Feuerman, M., King, A., Sriraman, R. & Khan, F. A. (1999). Effect of combined kinetic therapy and percussion therapy on the resolution of atelectasis in critically ill patients. *Chest*, 115 (6), 1658-1666.

Reeve, J., Denehy, L. & Stiller, K. (2007). The physiotherapy management of patients undergoing thoracic surgery: a survey of current practice in Australia and New Zealand. *Physiotherapy Research International*, 12 (2), 59-71.

Renault, J. A., Costa-Val, R. & Rossetti, M. B. (2008). Respiratory physiotherapy in the pulmonary dysfunction after cardiac surgery. *Brazilian Journal of Cardiovascular Surgery*, 23 (4), 562-569.

Renault, J. A., Costa-Val, R., Rosseti, M. B. & Houri-Neto, M. (2009). Comarison between deep breathing exercises and incentive spirometry after CABG surgery. *Brazilian Journal of Cardiovascular Surgery*, 24 (2), 165-172.

Restrepo, R. D., Wettstein, R., Wittnebel, L. & Tracy, M. (2011). American Association for Respiratory Care (AARC) Clinical Practice Guideline: incentive spirometry. *Respiratory Care*, 56 (10), 1600-1604.

Rezaiguia, S. & Jayr, C. (1996). Prevention of respiratory complications after abdominal surgery. *French Journal of Anesthesia and Intensive Care*, 15, 623-646.

Richard, W., Venker, J., den Herder, C., Kox, D., van den Berg, B., Laman, M., van Tinteren, H. & de Vries, N. (2007). Acceptance and long-term compliance of nCPAP in obstructive sleep apnea. *European Archives of Oto-rhino-laryngology*, 264 (9), 1081-1086.

Ricksten, S. E., Bengtsson, A., Soderberg, C., Thorden, M. & Kvist, H. (1986). Effects of periodic positive airway pressure by mask on postoperative pulmonary function. *Chest*, 89 (6), 774-781.

Rideau, Y., Gatin, G., Bach, J. & Gines, G. (1983). Prolongation of life in Duchenne's muscular dystrophy. *Acta Neurologica Belgica*, 5, 118-24.

Ries, A. L., Make, B. J. & Reilly, J. J. (2008). Pulmonary rehabilitation in emphysema. *Proceedings of the American Thoracic Society*, 5, 524–529.

Rodrigues, A. J., Mendes, V., Ferreira, P. E., Xavier, M. A., Augusto, V. S., Bassetto, S. & Evora, P. R. (2011). Preoperative respiratory muscle dysfunction is a predictor of prolonged invasive mechanical ventilation in cardiorespiratory complications after heart valve surgery. *European Journal of Cardiothoracic Surgery*, 39 (5), 662-666.

Romanini, W., Muller, A. P., Carvalho, K. A., Olandoski, M., Faria-Neto, J. R., Mendes, F. L., Sardetto, E. A., Costa, F. D. & Guarita-Souza, L. C. (2007). The effects of intermittent pressure and incentive spirometry in the postoperative of myocardial revascularization. Arquivos Brasileiros de Cardiologia, 89 (2), 94-110.

Ruppel, G. L. (2012). What is the clinical value of lung volumes? *Respiratory Care*, 57 (1), 26-35.

Ryan, S., Doherty, L. S., Nolan, G. M. & McNicholas ,W. T. (2009). Effects of heated humidification and topical steroids on compliance, nasal symptoms, and quality of life in patients with obstructive sleep apnea syndrome using nasal continuous positive airway pressure. *Journal of Clinical Sleep Medicine,* 5 (5), 422-427.

Ryan, S., Garvey, J. F., Swan, V., Behan, R. & McNicholas, W. T. (2011). Nasal pillows as an alternative interface in patients with obstructive sleep apnoea syndrome initiating continuous positive airway pressure therapy. *Journal of Sleep Research*, 20 (2), 367-373.

Sakamoto, K., Furuya, N. & Kanai, H. (2007). Optical characteristics of flowing blood: effects on the pulse oximeter. *IEEE Engineering in Medicine and Biology*, 2007, 4552-4555.

Saudi Ministry of Health. (2007). Statistic Book. Chapter 1. Statistics Department Web site. [Accessed February 4, 2013]. Available from URL: http://www.moh.gov.sa/statistics/stats2007/Book%20Seha02.pdf.

Saxena, P., Luthra, S., Dhaliwal, R. S., Rana, S. S. & Behera, D. (2007). Early changes in pulmonary functions after mitral valve replacement. *Annals of Thoracic Medicine*, 2 (3), 111-117.

Scanlan, C. L., Spearman, C. B. & Sheldon, R. L. (1995). Functional anatomy of the respiratory system. *Egan's fundamentals of respiratory care* (6th edition), St. Louis, MO; Mosby.

Scharf, S. M., Seiden, L., DeMore, J. & Carter-Pokras, O. (2004). Racial difference in clinical presentation of patients with sleep-disordered breathing. *Sleep and Breath*, 8, 173-183.

Schuller, D. & Morrow, L. E. (2000). Pulmonary complications after coronary revascularization. *Current Opinion in Cardiology Journal*, 15 (5), 309-315.

Schwieger, I., Gamulin, Z., Forster, A., Meyer, P., Gemerle, M. & Suter, P. M. (1986). Absence of benefit of incentive spirometry in low-risk patients undergoing elective cholecystectomy. Acontrolled randomized study. *Chest*, 89 (5), 652-656.

Scuderi, J. & Olsen, G. N. (1989). Respiratory therapy in the management of postoperative complications. *Respiratory Care*, 34, 281-291.

Sharafkhaneh, A., Falk, J. A., Minai, O. A. & Lipson, D. A. (2008). Overview of the perioperative management of lung volume reduction surgery patients. *Proceedings of the American Thoracic Society*, 5 (4), 438-441.

Silverman, R. A., Flaster, E., Enright, P. L. & Simonson, S. G. (2007). FEV1 performance among patients with acute asthma: results from a multicenter clinical trial. *Chest*, 131 (1), 164-171.

Singer, J., Yelin, E. H., Katz, P. P., Sanchez, G., Iribarren, C., Eisner, M. D. & Blanc, P. D. (2012). Respiratory and skeletal muscle strength in chronic obstructive pulmonary disease: impact on exercise capacity and lower extremity function. *Journal of Cardiopulmonary Rehabilitation and Prevention*, 31 (2), 111-119.

Smetana, G. W. (1999). Preoperative pulmonary evaluation. *The New England Journal of Medicine*, 340 (12), 937-944.

Smetana, G. W. (2003). Preoperative pulmonary assessment of the older adult. *Clinics in Geriatric Medicine*, 19 (1), 35-55.

Smith, I., Nadig, V. & Lasserson, T. J. (2009). Educational, supportive and behavioural interventions to improve usage of continuous positive airway pressure machines for adults with obstructive sleep apnoea. *The Cochrane Database of Systematic Reviews*, 15, (2), CD007736.

Smith, L. J., Arynchyn, A., Kalhan, R., Williams, O. D., Jensen, R., Crapo, R. & Jacobs, D. R. (2010). Spirometry guidelines influence lung function results in a longitudinal study of young adults. *Respiratory Medicine*, 104 (6), 858-864.

Sopkova, Z., Dorkova, Z. & Tkacova, R. (2009). Predictors of compliance with continuous positive airway pressure treatment in patients with obstructive sleep apnea and metabolic syndrome. *Wiener Klinische Wochenschrift*, 121 (11), 398-404.

Stiller, K., Montarello, J., Wallace, M., Daff, M., Grant, R., Jenkins, S. & et al. (1994). Efficacy of breathing and coughing exercises in the prevention of pulmonary complications after coronary artery surgery. *Chest*, 105(3), 741–7.

Stock, M. C., Downs, J.B., Cooper, R. B., Lebenson, I. M., Cleveland, J., Weaver, D. E., Alster, J. M. & Imrey, P. B. (1984). Comparison of continuous positive airway pressure, incentive spirometry, and conservative therapy after cardiac operations. *Critical Care Medicine*, 12 (11), 969-972.

Stock, M.C., Downs, J. B., Gauer, P. K., Alster, J. M. & Imrey, P. B. (1985). Prevention of postoperative pulmonary complication with CPAP, incentive spirometry, and conservative therapy. *Chest*, 87 (2), 151-157.

Sugiura, T., Noda, A., Nakata, S., Yasuda, Y., Soga, T., Miyata, S., Nakai, S. & Koike, Y. (2007). Influence of nasal resistance on initial acceptance of continuous positive airway pressure in treatment for obstructive sleep apnea syndrome. *Respiration*, 74 (1), 56-60.

Sullivan, C. E., Issa, F. G., Berthon-Jones, M. & Eves, L. (1981). Reversal of obstructive sleep apnoea by continuous positive airway pressure applied though the nose. *Lancet*, 1, 862-865.

Tang, C. Y., Taylor, N. F. & Blackstock, F. C. (2010). Chest physiotherapy for patients admitted to hospital with an acute exacerbation of chronic obstructive pulmonary disease (COPD): a systematic review. *Physiotherapy*, 96 (1), 1-13.

Tavolaro, K. C., Guizilini, S., Bolzan, D. W., Dauar, R. B., Buffolo, E., Succi, J. E. & Gomes, W. J. (2010). Pleural opening impairs respiratory system compliance and resistance in off-pump coronary artery bypass grafting. *The Journal of Cardiovascular Surgery*, 51 (6), 935-939.

Taylor, N. F., Dodd, K. J., Shields, N. & Bruder, A. (2007). Therapeutic exercise in physiotherapy practice is beneficial: a summary of systematic reviews 2002-2005. *The Australian Journal of Physiotherapy*, 53 (1), 7-16.

Thomas, J. A. & McIntosh, J. M. (1994). Are incentive spirometry, intermittent positive pressure breathing, and deep breathing exercises effective in the prevention of postoperative pulmonary complication after upper abdominal surgery? A systemic overview and meta-analysis. *Physical Therapy*, 74 (1), 3-16.

Thoren, L. (1954). Post-operative pulmonary complications: observations on their prevention by means of physiotherapy. *Acta Chirurgica Scandinavica*, 107 (2), 193-205.

Thorn, J., Tilling, B., Lisspers, K., Jorgensen, L., Stenling, A. & Stratelis, G. (2012). Improved prediction of COPD in at-risk patients using lung function pre-screening in primary care: a real-life study and cost-effectiveness analysis. *Primary Care Respiratory Journal*, 21 (2), 159-166.

Thys, F., Roeseler, J., Reynaert, M., Liistro, G. & Rodenstein, D. O. (2002). Noninvasive ventilation for acute respiratory failure: a prospective randomized placebo-controlled trial. *The European Respiratory Journal*, 20 (3), 545-555.

Treschan, T. A., Kaisers, W., Schaefer, M.S., Bastin, B., Schmalz, U., Wania, V., Eisenberger, C. F., Saleh, A., Weiss, M., Schmitz, A., Kienbaum, P., Sessler, D. I., Pannen, B. & Beiderlinden, M. (2012). Ventilation with low tidal volumes during upper abdominal surgery does not improve postoperative lung function. *British Journal of Anaesthesia*, 109 (2), 263-271.

Tschernko, E. M., Bambazek, A., Wisser, W., Partik, B., Jantsch, U., Kubin, K., Ehrlich, M., Klimscha, W., Grimm, M. & Keznickl, F. P. (2002). Intrapulmonary shunt after cardiopulmonary bypass: the use of vital capacity maneuvers versus off-pump coronary artery bypass grafting. *The Journal of Thoracic and Cardiovascular Surgery*, 124 (4), 732-738.

Tucker, B., Jenkins, S., Davies, K., McGann, R., Waddell, J., King, R., Kirby, V. & Lloyd, C. (1996). The physiotherapy management of patients undergoing coronary artery surgery: A questionnaire survey. *The Australian Journal of Physiotherapy*, 42 (2), 129-137.

Turner, J., Wright, E., Mendella, L. & Anthonisen, N. (1995). Predictors of patient adherence to long-term home nebulizer therapy for COPD. The IPPB Study Group. Intermittent Positive Pressure Breathing. *Chest*, 108 (2), 394-400.

Urell, C., Emtner, M., Hedenstrom, H., Tenling, A., Breidenskog, M. & Westerdahl, E. (2011). Deep breathing exercises with positive expiratory pressure at a higher rate improve oxygenation in the early period after cardiac surgery: a randomised controlled trial. *European Journal of Cardiothoracic Surgery*, 40 (1), 162-167.

Valdez-Lowe, C., Ghareeb, S. A. & Artinian, N. T. (2009). Pulse oximetry in adults. *The American Journal of Nursing*, 109 (6), 52-59.

Van Cauwenberge, P., Sys, L., De Belder, T. & Watelet, J. B. (2004). Anatomy and physiology of the nose and the paranasal sinuses. *Immunology and Allergy Clinics of North America*, 24 (1), 1-17.

Vandevoorde, J., Verbanck, S., Schuermans, D., Kartounian, J. & Vincken, W. (2006). Obstructive and restrictive spirometric patterns: fixed cut-offs for FEV1/FEV6 and FEV6. *The European Respiratory Journal*, 27 (2), 378-383.

Varekojis, S. M., Douce, F. H., Flucke, R. L., Filbrun, D. A., Tice, J. S., McCoy, K. S. & Castile, R. G. (2003). A comparison of the therapeutic effectiveness of and preference for postural drainage and percussion, intrapulmonary percussive ventilation, and high-frequency chest wall compression in hospitalized cystic fibrosis patients. *Respiratory Care*, 48 (1), 24-28.

Vargas, F. S., Cukier, A., Terra-Filho, M. & et al. (1993). Influence of atelectasis on pulmonary function after coronary artery bypass grafting. *Chest*, 104, 434–437.

Vargas, F. S., Terra-Filho, M., Hueb, W., Teixeira, L. R., Cukier, A. & Light, R. W. (1997). Pulmonary function after coronary artery bypass surgery. *Respiratory Medicine*, 91 (10), 629-633.

Varnauskas, E. (1988). Twelve-year follow-up of survival in the randomized European Coronary Surgery Study. *The New England Journal of Medicine*, 319 (6), 332-337.

Veering, B. T. (2003). Cardiovascular and pulmonary effects of epidural anaesthesia. *Minerva Anestesiologica*, 69(5), 433-437.

Wang, C. H., Lin, H. C., Huang, T. J., Yang, T. C., Yu, C. T. & Kuo, H. P. (1996). Differential effects of nasal continuous positive airway pressure on reversible or fixed upper and lower airway obstruction. *The European Respiratory Journal*, 9, 952–959.

Warner, D. O. (2006). Perioperative abstinence from cigarettes: physiologic and clinical consequences. *Anesthesiology*, 104 (2), 356-367.

Warner, M. A., Offord, K. P., Warner, M. E., Lennon, R. L., Conover, M. A. & Jansson-Schumacher, U. (1989). Role of preoperative cessation of smoking and other factors in postoperative pulmonary complications: a blinded prospective study of coronary artery bypass patients. *Mayo Clinic Proceedings*, 64, 609–616.

Weaver, T. E. & Grunstein, R. R. (2008). Adherence to continuous positive pressure therapy: the challenge to effective treatment. *Proceedings of the American Thoracic Society*, 15 (2), 173-178.

Weaver, T. E. (2001). Adherence to CPAP treatment and functional status in adult obstructive sleep apnea. In: Pack AI, editor. *Sleep apnea: pathogenesis, diagnostic and treatment*. New York: Marcel Decker.

Weaver, T. E., Maislin, G., Dinges, D. F., Bloxham, T., George, C. F., Greenberg, H., Kader, G., Mahowald, M., Younger, J. & Pack, A. I. (2007). Relationship between hours of CPAP use and achieving normal levels of sleepiness and daily functioning. *Sleep*, 30, 711-719.

Weindler, J. & Kiefer, R.T. (2001). The efficacy of postoperative incentive spirometry is influenced by the device-specific imposed work of breathing. *Chest*, 119(6):1858-1864.

Weissman, C. (2004). Pulmonary complications after cardiac surgery. *Seminars in Cardiothoracic and Vascular Anesthesia*, 8 (3), 185-211.

Westerdahl, E. & Olsen, M. F. (2011). Chest physiotherapy and breathing exercises for cardiac surgery patients in Sweden--a national survey of practice. *Monaldi Archives for Chest Disease*, 75 (2), 112-119.

Westerdahl, E., Lindmark, B., Almgren, S. & Tenling, A. (2001). Chest physiotherapy after coronary artery bypass graft surgery- A comparison of three different deep breathing techniques. *Journal of Rehabilitation Medicine*, 33, 79-84.

Westerdahl, E., Lindmark, B., Bryngelsson, I. & Tenling, A. (2003). Pulmonary function 4 months after coronary artery bypass graft surgery. *Respiratory Medicine*, 97, 317-322.

Westerdahl, E., Lindmark, B., Eriksson, T., Friberg, O., Hedenstierna, G. & Tenling, A. (2005). Deep-breathing exercises reduce atelectasis and improve pulmonary function after coronary artery bypass surgery. *Chest*, 128 (5), 3482-3488.

Westwood, K., Griffin, M., Roberts, K., Williams, M., Yoong, K. & Digger, T. (2007). Incentive spirometry decreases respiratory complications following major abdominal surgery. *Surgeon*, 5 (6), 339-342.

White G. (2012): *Basic Clinical Lab Competencies for Respiratory Care* (5th edition), New York. Delmar Cengage learning. Clifton park.

Wilkins, R. L. & Wehrman, S. F. (2009). Applied Anatomy and Physiology. *Workbook for Egan's Fundamentals of Respiratory Care* (9th Edition). New York, Mosby.

Wilson, B. J., Cowan, H. J., Lord, J. A., Zuege, D. J. & Zygun, D. A. (2010). The accuracy of pulse oximetry in emergency department patients with severe sepsis and septic shock: a retrospective cohort study. *BMC Emergency Medicine*, 10, 9.

Wukitsch, M. W., Petterson, M. T., Tobler, D. R. & Pologe, J. A. (1988). Pulse oximetry: analysis of theory, technology, and practice. *Journal of Clinical Monitoring*, 4 (4), 290-301.

Wynne, R. & Botti, M. (2004). Postoperative pulmonary dysfunction in adults after cardiac surgery with cardiopulmonary bypass: clinical significance and implications for practice. *American Journal of Respiratory and Critical Care Medicine*, 13, 384–393.

Xavier, M. A., Ceneviva, R., Terra, Filho. J. & Sankarankutty, A. K. (2010). Pulmonary function and quality of life in patients with morbid obesity six months after bariatric surgery. *Acta Cirurgica Brasileira,* 25 (5), 407-415.

Yanez-Brage, I., Pita-Fernandez, S., Juffe-Stein, A., Martinez-Gonzalez, U., Pertega-Diaz, S. & Mauleon-Garcia, A. (2009). Respiratory physiotherapy and incidence of pulmonary complications in off-pump coronary artery bypass graft surgery: an observational follow-up study. *BioMed Central Pulmonary Medicine,* 9, 36.

Zarbock, A., Mueller, E., Netzer, S., Gabriel, A., Feindt, P. & Kindgen-Milles, D. (2009). Prophylactic nasal continuous positive airway pressure following cardiac surgery protects from postoperative pulmonary complications: a prospective, randomized, controlled trial in 500 patients. *Chest,* 135 (5), 1252-1259.

Zibrak, J. D., O'Donnell, C. R. (1993). Indications for preoperative pulmonary function testing. *Clinics in Chest Medicine,* 14 (2), 227-236.

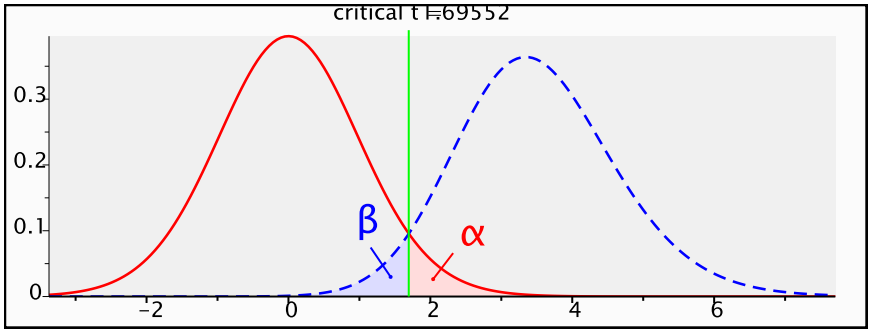
Zoremba, M., Dette, F., Gerlach, L., Wolf, U. & Wulf, H. (2009). Short-term respiratory physical therapy treatment in the PACU and influence on postoperative lung function in obese adults. *Obesity Surgery*, 19 (10), 1346-1354.

Zozula, R. & Rosen, R. (2001). Compliance with continuous positive airway pressure therapy: assessing and improving treatment outcomes. *Current Opinion in Pulmonary Medicine,* 7 (6), 391-398.

RESEARCH APPENDIX

Appendix A. G. power calculation for estimated sample size for pilot study

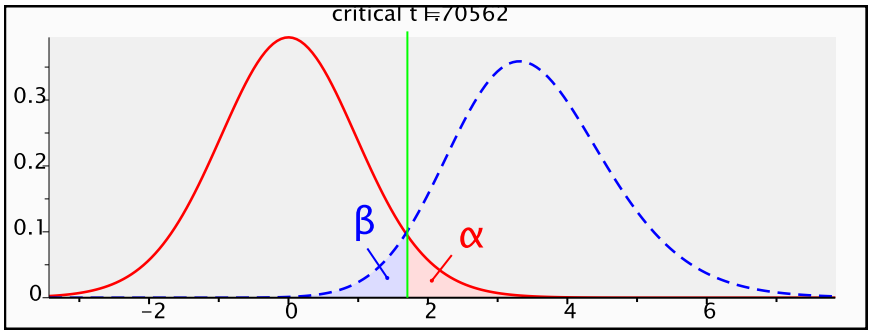
Estimated sample size for pilot study (IS group)



t tests – Means: Difference between two dependent means (matched pairs)

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	One
	Effect size dz	=	0.6047432
	α err prob	=	0.05
	Power (1−β err prob)	=	0.95
Output:	Noncentrality parameter δ	=	3.4209441
	Critical t	=	1.6955188
	Df	=	31
	Total sample size	=	32
	Actual power	=	0.9554351

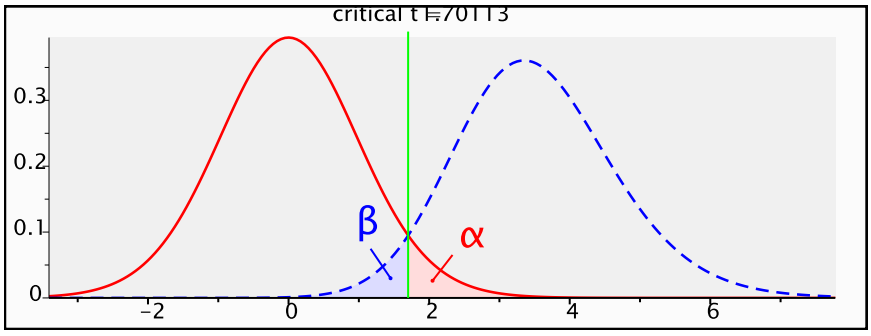
Estimated sample size for pilot study (CPAP2hrs group)



t tests – Means: Difference between two dependent means (matched pairs)

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	One
	Effect size dz	=	0.6546537
	α err prob	=	0.05
	Power (1−β err prob)	=	0.95
Output:	Noncentrality parameter δ	=	3.4016804
	Critical t	=	1.7056179
	Df	=	26
	Total sample size	=	27
	Actual power	=	0.9521759

Estimated sample size for pilot study (CPAP4hrs group)



t tests – Means: Difference between two dependent means (matched pairs)

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	One
	Effect size dz	=	0.6378077
	α err prob	=	0.05
	Power (1−β err prob)	=	0.95
Output:	Noncentrality parameter δ	=	3.4346996
	Critical t	=	1.7011309
	Df	=	28
	Total sample size	=	29
	Actual power	=	0.9559118

Appendix B. King Fahd Armed Forces hospital ethical approval:

KING FAHD ARMED FORCES HOSPITAL
P.O. BOX : 9862 JEDDAH 21159
KINGDOM OF SAUDI ARABIA

مستشفى الملك فهد للقوات المسلحة
ص . ب : ٩٨٦٢ جـــــدة ٢١١٥٩
المملكة العربية السعودية

November 7, 2009

To : **Mr. Fouad Al-Mutairi**
Principal Investigator / Research Student

From : **Dr. Mohd Shankiti**
Acting Chairman of Research Ethics Committee

Subject: **Research Proposal: Alternative Method To Treat Atelectasis**

At the recent Research Ethics Committee meeting held on November 4, 2009 and upon reviewing your above mentioned research proposal, it was the recommendation of committee that you can proceed with your research proposal.

Thank you.

Regards,

Dr. Mohd Shankiti
Acting Chairman of Research Ethics Committee

Cc: All Research Ethics Committee members
Committee File

001-37925

Appendix C. Copy of the abstract of the first study published article:

Abstract

OBJECTIVE:

To assess the effect of early use of continuous positive airway pressure (CPAP) therapy to treat or prevent acute atelectasis in post-operative cardiac patients particularly smokers and elderly patients.

METHODS:

A pilot study suggested enrolling at least 32 participants in each group to be significant. One hundred and eight patients from King Fahd Armed Forces Hospital, Jeddah, Kingdom of Saudi Arabia who met the inclusion criteria participated in this study conducted between March 2010 and March 2011. The participants were divided randomly into 3 groups, incentive spirometry (IS) therapy, and CPAP therapy every 2 (CPAP2hrs), or 4 hours (CPAP4hrs). Inspiratory capacity (IC) was used to compare the 3 therapy regimes. Simultaneously, respiratory rate (RR), heart rate (HR) and oxygen saturation (SpO2) were measured for all groups. Failure was defined as requiring intubation, bi-level positive airway pressure, or added chest physiotherapy.

RESULTS:

Thirty-six patients participated in each group (98 male and 10 female, with a mean age of 62+/-9.3 years). The IC increased significantly in the CPAP2hrs group when compared with the control group or the CPAP4hrs group. The SpO2 decreased significantly in the control group and the CPAP4hrs groups when compared with the CPAP2hrs group. Also, there were no significant differences in RR and HR between all groups.

CONCLUSION:

Early use of CPAP via mask therapy for half an hour every 2 hours had better outcomes to re-open collapsed alveoli after cardiac surgery.

Article reference;

Al-Mutairi, F. H., Fallows, S. J., Abukhudair, W. A., Islam, B. B. & Morris M. M. (2012). Difference between continuous positive airway pressure via mask therapy and incentive

spirometry to treat or prevent post-surgical atelectasis. *Saudi Medical Journal*, 33 (11), 1190-1195.

Appendix D. Presented abstract at European Respiratory

Society Annual Conference:

ERS EUROPEAN RESPIRATORY SOCIETY

CERTIFICATE OF Oral Presentation
PRESENTATION

This confirms that

Fouad ALMutairi

presented the abstract entitled:

"The effect of early use of continuous positive airway pressure (CPAP) therapy to treat acute atelectasis after cardiac surgery: Randomized study"

in the Oral Presentation session entitled:

"Sleep and weight: heavy under pressure"

on 27 September 2011
during the ERS Amsterdam Congress.

Carine Pannetier
Head of Scientific Activities

Appendix E. Consent form for the first study:

Consent Form (English Copy)

Study title: Difference between continuous positive airway pressure via mask therapy and incentive spirometry to treat or prevent post- surgical atelectasis: prospective randomized study

Consent Form for Patients **Date: / /**

Name of Patient: _____

Patient NO: _____

I confirm that I have read and understand the information sheet dated / / "Difference between continuous positive airway pressure via mask therapy and incentive spirometry to treat or prevent post- surgical atelectasis: prospective randomized study**"** for this study and I have had the opportunity to ask questions.

I understand that my participation is voluntary and that I am free to withdraw at any time and without giving any reason or my legal rights being affected.

I confirm that I give permission for the researcher to have access to my records.

I agree to take part in the above study.

Name of patient: _____

Date: _____/_____/_____ Signature: _____

Name of researcher: _____

Date: _____/_____/_____ Signature: _____

University of Chester

Participant information sheet

"Title: Difference between continuous positive airway pressure via mask therapy and incentive spirometry to treat or prevent post- surgical atelectasis: prospective randomized study"

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?
The patients who have major surgery as a result of abdominal or thorax opening usually will have a collapsed lung (atelectasis). The regular treatment to re-open the collapsed area in the lung will involve IS therapy (Incentive Spirometry) 15 times every hour. However, some patients do not perform the IS therapy properly, which results in more complications after surgery which in turn sometimes lead to the need for advanced treatment such as intubations and ventilation to re- open the lung.

This study aims to compare CPAP therapy and the regular IS therapy to treat acute atelectasis in post- operative cardiac patients. Also, to assess the effect of early use of CPAP therapy to improve lung function, reduce hospital stay, reduce morbidity and mortality, and ensure early recovery from critical care units.

Why have I been chosen?
You have been chosen because you are a post op cardiac patient.

Do I have to take part?
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part?
You will be assess according to your condition, and once identified; you will be classified into one of the three study groups:
The Control group (IS group) – you will use the regular treatment. IS times 15 breaths for 3 days;
1st trial group (CPAP- 2hr) – you will use the CPAP therapy via mask for half an hour every 2 hours for 3 days;
Or 2nd trial group (CPAP- 4hr) – you will use the CPAP therapy via mask for half an hour every 4 hour for 3 days.

What are the possible disadvantages and risks of taking part?
There are no specific disadvantages or risks foreseen in taking part of the study.

If there be any circumstances that the participants cannot tolerate the procedure longer during in the course of the study or any problems arising that may detriment the life of the participant, the procedure will immediately stop and he will be in closed observation.

What are the possible benefits of taking part?
By taking part, you will be contributing to the new method of treating post- cardiac surgery patient with enhanced outcome.

What if something goes wrong?
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Mr. Fouad Al-mutairi, principal researcher, hospital tel. ext. – 2434/ 2369.

Will my taking part in the study be kept confidential?
All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?
The results will be written up into Research study for my PHD degree.

Who is organising and funding the research?
The researcher, University of Chester and government of Saudi Arabia.

Who may I contact for further information?
If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Fouad Al-mutairi. [redacted]

Note: All procedures in this research followed the King Fahd Armed Forces Hospital patient safety guidelines.

Thank you for your interest in this study.

Appendix F. Presented abstract at 32nd International Symposium on Intensive Care and Emergency Medicine conference:

32nd International Symposium on Intensive Care and Emergency Medicine: Poster Presentation

Dear Authors, Congratulations !

We are pleased to inform you that your abstract, entitled :

' Difference between CPAP via mask therapy plus CPT and IS therapy plus CPT to treat or prevent acute atelectasis after cardiac surgery '

has been accepted for poster presentation by the Scientific Committee.

Your poster has been assigned the number : P135 (P-number).

Your abstract will be published in a supplement issue of the journal Critical Care (included in the registration material).

A jury will select the best posters which will be awarded prizes of a total value of Euros 5,000.

If you have not registered yet, you must do so without delay.

Having submitted an abstract, you already have a profile on our system, so to register just click on the link:

http://www.intensive.org/1/m12I1.asp?L1=9&L2=1&L3=1&ety=1&step=2&mail=1&eventID=1079190526&intID=2123383197&evtID=1079190526 (Please do not create a new profile).

Without full registration as a participant you will not to be able to present your poster

INSTRUCTIONS FOR POSTER PRESENTATIONS

The poster board will provide an area that is 130 cm high by 90 cm wide so please insure your poster fits these dimensions. You can attach your material with drawing pins or with magic tape to your assigned poster board which will be marked with your poster number : P135 (P-number).

Poster set-up time

Monday, March 19, 2012 from 14.00 until 17.00

Poster display

Tuesday, March 20, 2012 at 11.00 until Friday, March 23, 2012 at 13.30

Poster presentation (author present)

Tuesday, March 20, 2012 from 18.00 until 19.00

A jury of experts will select the best poster on the basis of scientific content and presentation.

Poster award

Wednesday, March 21, 2012 in the Gold room - 15:35 - 15:45 (Total value: Euros 5,000)

Poster removal time Friday, March 23, 2012 at 13.30

We look forward to meeting you in Brussels.

Yours sincerely,

Colette Dutillieu

Congress Coordinator

Appendix G. Presented abstract at American Thoracic Society Conference:

The ATS International Conference Committee would like to inform you that your abstract listed below has been accepted for presentation at the 2012 ATS International Conference in San Francisco, California.

Your abstract was accepted and has been programmed as a Poster presentation in session:

Abs. ID/Title: #30931 - Continuous Positive Airway Pressure (CPAP) Had Better Outcomes When Compared With Incentive Spirometry (IS) To Re-Open Collapse Alveoli After Cardiac Surgery: Randomized Study

Presenter: F. Almutairi Session: C66 - INTEGRATED CARE AND PULMONARY REHABILITATION

Session Type: Thematic Poster Session- Poster Presentation

Date: Tuesday, May 22, 2012

Time: 8:15 AM-4:30 PM

Additional information about your presentation will follow in March.

You must register for the conference and we recommend you do this soon to take advantage of the early-bird registration fee and to ensure your choice of hotel. You may register online through the ATS Web site http://www.thoracic.org/go/international-conference. Take note of the reduced registration fee for those who return the form by the March 13 deadline. You are also responsible for making your own travel and hotel accommodations.

Please submit your poster by Monday, May 14 (11:59 PM Central Time). We will send you a reminder so you don't miss this opportunity to make your presentation easier.

Thank you for your participation. We look forward to an exciting program.

David Au, M.D.

Chair International Conference Committee

Appendix H. Consent form for the second study:

Consent Form (English Copy)

Study title: Difference between continuous positive airway pressure via mask therapy and incentive spirometry plus chest physiotherapy to treat or prevent post- surgical atelectasis: prospective randomized study.

Consent Form for Patients **Date: / /**

Name of Patient: _____

Patient NO: _____

I confirm that I have read and understand the information sheet dated / / "Difference between continuous positive airway pressure via mask therapy and incentive spirometry plus chest physiotherapy to treat or prevent post- surgical atelectasis: prospective randomized study**"** for this study and I have had the opportunity to ask questions.

I understand that my participation is voluntary and that I am free to withdraw at any time and without giving any reason or my legal rights being affected.

I confirm that I give permission for the researcher to have access to my records.

I agree to take part in the above study.

Name of patient: _____

Date: _____/_____/_____ Signature: _____

Name of researcher: _____

Date: _____/_____/_____ Signature: _____

University of Chester

Participant information sheet

"Title: Difference between continuous positive airway pressure via mask therapy and incentive spirometry plus chest physiotherapy to treat or prevent post- surgical atelectasis: prospective randomized study"

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?

This study aims to evaluate the effectiveness of adding chest physiotherapy to CPAP via mask therapy to treat or prevent post-surgical atelectasis as compared to Incentive spirometery therapy with chest physiotherapy.

Why have I been chosen?
You have been chosen because you are a post op cardiac patient.

Do I have to take part?
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part?
You will be assess according to your condition, and once identified; you will be classified into one of the two study groups:
IS plus CPT group – you will use the IS times 15 breaths per hour with CPT every 4 hours for 3 days, or CPAP2hrs plus CPT group – you will use CPAP therapy via mask for half an hour every 2 hours with CPT every 4 hours.

What are the possible disadvantages and risks of taking part?
There are no specific disadvantages or risks foreseen in taking part of the study.

If there be any circumstances that the participants cannot tolerate the procedure longer during in the course of the study or any problems arising that may detriment the life of the participant, the procedure will immediately stop and he will be in closed observation.

What are the possible benefits of taking part?
By taking part, you will be contributing to the new method of treating post- cardiac surgery patient with enhanced outcome.

What if something goes wrong?
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Mr. Fouad Al-mutairi, principal researcher, hospital tel. ext. – 2434/ 2369.

Will my taking part in the study be kept confidential?
All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?
The results will be written up into Research study for my PHD degree.

Who is organising and funding the research?
The researcher, University of Chester and government of Saudi Arabia.

Who may I contact for further information?
If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Fouad Al-mutairi. [redacted]

Note: All procedures in this research followed the King Fahd Armed Forces Hospital patient safety guidelines.

Thank you for your interest in this study.

Appendix I. Accepted abstract at American Thoracic Society Conference:

The ATS International Conference Committee would like to inform you that your abstract listed below has been accepted for presentation at the 2013 ATS International Conference in Philadelphia, Pennsylvania.

Your abstract was accepted and has been programmed as a POSTER presentation in session:

ID 40615 Post Cardiac Surgery Patients' Experiences Using Continuous Positive Airway Pressure (CPAP) Via Mask therapy To Treat Post-Surgical Atelectasis
D35-ISSUES IN THORACIC SURGERY
Thematic Poster Session- Poster Presentation
WEDNESDAY, MAY 22, 2013
8:15 AM-4:30 PM

Additional information about your presentation will follow in March.

You must register for the conference and we recommend you do this soon to take advantage of the early-bird registration fee and to ensure your choice of hotel. You may register online and access the virtual Advance Program through the ATS Web site http://www.thoracic.org/go/international-conference. You may also register by mail, facsimile and phone and can find more information about these methods in the virtual Advance Program. Take note of the reduced registration fee for those who return the form by the March 12 deadline. You are also responsible for making our own travel and hotel accommodations.
Thank you for your participation. We look forward to an exciting program.

David Au, M.D.
Chair
International Conference Committee

Appendix J. Copy of the questionnaire for patients' experience:

Study group & number:	
Patient number:	
Visit number:	
Date:	

The questionnaire will ask about the *compliance* and *periodicity* of the use of nasal CPAP. It also examines side-effects and symptoms in detail.

Please answer the following questions:

When did you start using your CPAP machine? _____

Do you use your CPAP machine every day? _____

No. of hours used each day _____

A - Do you currently suffer from any of the following?

Nasal blockage	Yes ☐	No ☐
Dryness in nose	Yes ☐	No ☐
Nose bleeds	Yes ☐	No ☐
Pain over bridge of nose	Yes ☐	No ☐
Excessive sneezing	Yes ☐	No ☐
Blood stained mucus from nose	Yes ☐	No ☐
Runny nose	Yes ☐	No ☐
Dry mouth/throat in the mornings	Yes ☐	No ☐
Mucus in throat	Yes ☐	No ☐
Dizziness	Yes ☐	No ☐
Sore eyes	Yes ☐	No ☐
Facial pains	Yes ☐	No ☐
Eczema	Yes ☐	No ☐
Hayfever	Yes ☐	No ☐
Asthma	Yes ☐	No ☐
Blocked ears	Yes ☐	No ☐

Have you had any of the above problems in the past? (Before starting CPAP therapy)
.....

B - WHAT IS YOUR EXPERIENCE OF THE FOLLOWING?

Noise of machine (Noisy)	Yes ☐	No ☐
Comfort of mask (Comfortable)	Yes ☐	No ☐
Air leaking from masks	yes ☐	No ☐
Air leaking from your mouth	Yes ☐	No ☐
Skin reaction to mask	Yes ☐	No ☐
Breakdown of skin over nose (i.e. Pressure sore)	Yes ☐	No ☐
Have you taken any inhalers/spray for nasal stuffiness?	Yes ☐	No ☐
Treatment benefit from the machine use	Yes ☐	No ☐

Any other experiences/problems?

_____

_____

_____

_____

Thank you for your time and co-operation in this study.

Appendix K. Consent form for the third study:

Consent Form (English Copy)

Study title: Post cardiac surgery patients' experiences using continuous positive airway pressure (CPAP) via mask therapy to treat post-surgical atelectasis.

Consent Form for Patients **Date: / /**

Name of Patient: _____

Patient NO: _____

I confirm that I have read and understand the information sheet dated / / "Post cardiac surgery patients' experiences using continuous positive airway pressure (CPAP) via mask therapy to treat post-surgical atelectasis.**"** for this study and I have had the opportunity to ask questions.

I understand that my participation is voluntary and that I am free to withdraw at any time and without giving any reason or my legal rights being affected.

I confirm that I give permission for the researcher to have access to my records.

I agree to take part in the above study.

Name of patient: _____

Date: _____/_____/_____ Signature: _____

Name of researcher: _____

Date: _____/_____/_____ Signature: _____

Appendix L. Consent form for the fourth study:

Consent Form (English Copy)

Study title: The experience of medical staff about the use of CPAP via mask therapy to treat or prevent post-surgical atelectasis after CABG.

Consent Form for Patients **Date: / /**

Name of Patient: _____

Patient NO: _____

I confirm that I have read and understand the information sheet dated / /
"The experience of medical staff about the use of CPAP via mask therapy to treat or prevent post-surgical atelectasis after CABG**"** for this study and I have had the opportunity to ask questions.

I understand that my participation is voluntary and that I am free to withdraw at any time and without giving any reason or my legal rights being affected.

I confirm that I give permission for the researcher to have access to my records.

I agree to take part in the above study.

Name of patient: _____

Date: _____/_____/_____ Signature: _____

Name of researcher: _____

Date: _____/_____/_____ Signature: _____

Appendix M. Samples of medical staff interview:

Medical staff interview for new CPAP method of therapy research

1- What is your medical back ground and how many years of experience do you have in the post-cardiac surgery field?
ANSWER: ***I'm working as RT since 1988 and I've been working with post cardiac surgery patient for 17 years.***

2- Have you worked with the new methods of CPAP therapy before? If yes, please explain.
ANSWER: ***Yes, when the others lung expand therapy (IS and DBE) became not effective, we used the CPAP therapy for post operative patient to keep the lungs open so as to prevent atelectasis and improve oxygenation.***

3- In your opinion, what is the difference between the new methods of CPAP therapy and the regular IS therapy to prevent or treat post-cardiac surgery atelectesis?
ANSWER: ***In CPAP therapy patient doesn't need to exert effort just to open up their lungs. The machine will help to keep the lungs open even they are in pain since this is the most common cause of atelectasis and most of the patient able to sleep and tolerate this new method.***
In IS therapy, if the patient is in their old age, it's hard for them to do IS well since their pain threshold is low compare to the young ones. And sometimes, most of them are complaining that they don't want to do it because they want to sleep.

4- Would you agree to use the new methods of CPAP therapy with your patients in the future? If your answer is NO, please explain why.
ANSWER: ***Yes.***

5- In your opinion, what are the advantages and the disadvantages of the new CPAP methods of therapy to treat or prevent post-cardiac surgery atelectasis?
ANSWER: ***The advantages of CPAP is to prevent atelectasis, increase functional residual capacity, improved oxygenation, lessen the length of stay of patient in the hospital.***
I don't have experienced that patient become hypotensive due to CPAP therapy.

6- Do you prefer to use CPAP therapy every two hours or every four hours?
ANSWER: ***I would prefer every four (4) hours, so as the patient can able to sleep well, not to disturbed them every two (2) hours, since I believed that after operation they need to gain the strength and power to overcome the procedure they have.***

7- Do you think the new methods of CPAP therapy are easy to understand and use?
ANSWER: ***Yes.***

……

Medical staff interview for new CPAP method of therapy research

1- What is your medical back ground and how many years of experience do you have in the post-cardiac surgery field?
ANSWER: ***Coronary Care Unit Respiratory Therapeutic Supervisor and 16 years of experience.***

2- Have you worked with the new methods of CPAP therapy before? If yes, please explain.
ANSWER: ***NO***

3- In your opinion, what is the difference between the new methods of CPAP therapy and the regular IS therapy to prevent or treat post-cardiac surgery atelectasis?
ANSWER: ***CPAP therapy needs less effort from the patient but give continuous positive pressure even patient asleep. IS needs more effort and explanation to the patient.***

4- Would you agree to use the new methods of CPAP therapy with your patients in the future? If your answer is NO, please explain why.
ANSWER: ***YES***

5- In your opinion, what are the advantages and the disadvantages of the new CPAP methods of therapy to treat or prevent post-cardiac surgery atelectasis?
ANSWER: ***Advantage easy to apply to the patient even patient with low pain tolerance. Disadvantage if you apply to the patient causing gastric bubbles.***

6- Do you prefer to use CPAP therapy every two hours or every four hours?
ANSWER: Every *two hours*

7- Do you think the new methods of CPAP therapy are easy to understand and use?
ANSWER: ***YES***

Medical staff interview for new CPAP method of therapy research

1- What is your medical back ground and how many years of experience do you have in the post-cardiac surgery field?
ANSWER: I worked as intensivist for *8 years in ICU (general) and 4 years in Post Cardiac Surgery.*

2- Have you worked with the new methods of CPAP therapy before? If yes, please explain.
ANSWER: *NO*

3- In your opinion, what is the difference between the new methods of CPAP therapy and the regular IS therapy to prevent or treat post-cardiac surgery atelectasis?
ANSWER: *CPAP therapy is most effective as a positive pressure therapy to prevent atelactesis.*

4- Would you agree to use the new methods of CPAP therapy with your patients in the future? If your answer is NO, please explain why.
ANSWER: *YES*

5- In your opinion, what are the advantages and the disadvantages of the new CPAP methods of therapy to treat or prevent post-cardiac surgery atelectasis?
ANSWER: *Advantages, positive pressure preventing or improving atelectasis and very easy to be used bed side without consumption of patient effort and without inducing pain. Advantages, no effective in patients with a lot of secretion who needs cough exercise beside CPAP therapy.*

6- Do you prefer to use CPAP therapy every two hours or every four hours?
ANSWER: *Every 2 hours in D0 and D1.*

7- Do you think the new methods of CPAP therapy are easy to understand and use?
ANSWER: *YES*

Medical staff interview for new CPAP method of therapy research

1- What is your medical back ground and how many years of experience do you have in the post-cardiac surgery field?
ANSWER: ***I'm a cardiac surgeon for 30 years.***

2- Have you worked with the new methods of CPAP therapy before? If yes, please explain.
ANSWER: ***No.***

3- In your opinion, what is the difference between the new methods of CPAP therapy and the regular IS therapy to prevent or treat post-cardiac surgery atelectesis?
ANSWER: ***New methods of CPAP therapy were very good, since many patients avoided re-intubation.***

4- Would you agree to use the new methods of CPAP therapy with your patients in the future? If your answer is NO, please explain why.
ANSWER: ***Yes.***

5- In your opinion, what are the advantages and the disadvantages of the new CPAP methods of therapy to treat or prevent post-cardiac surgery atelectasis?
ANSWER: ***CPAP was more effective in oxygen saturation and atelectasis. Disadvantage was Gastric distention.***

6- Do you prefer to use CPAP therapy every two hours or every four hours?
ANSWER: ***CPAP therapy every two hours.***

7- Do you think the new methods of CPAP therapy are easy to understand and use?
ANSWER: ***Yes.***

Medical staff interview for new CPAP method of therapy research

1- What is your medical back ground and how many years of experience do you have in the post-cardiac surgery field?
ANSWER: ***CCU nurse for nine (9) years.***

2- Have you worked with the new methods of CPAP therapy before? If yes, please explain.
ANSWER: ***No.***

3- In your opinion, what is the difference between the new methods of CPAP therapy and the regular IS therapy to prevent or treat post-cardiac surgery atelectasis?
ANSWER: ***New CPAP method therapy is continuous treatment while patient is on bed or in pain, while IS therapy patient must in sitting position and helps to reduce pain.***

4- Would you agree to use the new methods of CPAP therapy with your patients in the future? If your answer is NO, please explain why.
ANSWER: ***Yes.***

5- In your opinion, what are the advantages and the disadvantages of the new CPAP methods of therapy to treat or prevent post-cardiac surgery atelectasis?
ANSWER: ***Advantage: helps to prevent atelectasis.***
Disadvantage: ***develop gastric distention.***

6- Do you prefer to use CPAP therapy every two hours or every four hours?
ANSWER: ***two (2) hours on day one.***

7- Do you think the new methods of CPAP therapy are easy to understand and use?
ANSWER: ***yes.***

Medical staff interview for new CPAP method of therapy research

1- What is your medical back ground and how many years of experience do you have in the post-cardiac surgery field?
ANSWER: ***Registered nurse for four (4) years.***

2- Have you worked with the new methods of CPAP therapy before? If yes, please explain.
ANSWER: ***No.***

3- In your opinion, what is the difference between the new methods of CPAP therapy and the regular IS therapy to prevent or treat post-cardiac surgery atelectasis?
ANSWER: ***You can still continue the treatment with patient with low pain threshold while IS need more effort.***

4- Would you agree to use the new methods of CPAP therapy with your patients in the future? If your answer is NO, please explain why.
ANSWER: ***Yes.***

5- In your opinion, what are the advantages and the disadvantages of the new CPAP methods of therapy to treat or prevent post-cardiac surgery atelectasis?
ANSWER: ***Advantage: It can improve atelectasis.***
Disadvantages: CPAP cannot give patient with more secretions a nebulization and do coughing exercises.

6- Do you prefer to use CPAP therapy every two hours or every four hours?
ANSWER: ***Every two (2) hours.***

7- Do you think the new methods of CPAP therapy are easy to understand and use?
ANSWER: ***Yes.***